CODE FOR ELECTRICITY METERS

THIRD EDITION

A. E. S. C. Standard No. C12—1928

CODE FOR ELECTRICITY METERS

Prepared by a Sectional Committee according to the Procedure of the American Engineering Standards Committee under the joint sponsorship of the

ASSOCIATION OF EDISON ILLUMINATING COMPANIES
NATIONAL ELECTRIC LIGHT ASSOCIATION
UNITED STATES BUREAU OF STANDARDS

THIRD EDITION

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PREFACE TO THE THIRD EDITION

This edition of the Code for Electricity Meters is a completely revised and rearranged compilation of the Second Edition, issued in 1912, and the section on Demand Meters, issued in 1920. The 1912-20 edition of the code was approved as American Standard by the American Engineering Standards Committee in July, 1922 (C12-1922). The present revision has been made under the joint sponsorship of the Association of Edison Illuminating Companies, the National Electric Light Association and the U. S. Bureau of Standards by a Sectional Committee representing all interested organizations, in accordance with the procedure established by the American Engineering Standards Committee for the revision of American Standards.

The sponsors hereby express their appreciation to the members of the Sectional Committee and their associates for the painstaking and careful manner in which the revision was carried out.

February 20, 1928.

Historical Note

The Sectional Committee on Revision of the Code for Electricity Meters was organized by a committee representing the sponsors as follows:

Association of Edison Illuminating Companies

O. J. Bushnell, Commonwealth Edison Company, Chicago, Ill.
F. V. Magalhaes, The New York Edison Company, New York City.

National Electric Light Association

Alexander Maxwell, National Electric Light Association, New York City.
Burleigh Currier, Philadelphia Electric Company, Philadelphia, Pa.
W. L. Wadsworth, Northern States Power Company, Minneapolis, Minn.

U. S. Bureau of Standards

J. Franklin Meyer, Bureau of Standards, Washington, D. C.

The complete personnel of the committee and the organizations represented was as follows:

Name	*Representation*	*Address*
R. W. Eaton	American Electric Railway Association	Public Service Engineer, Providence, R. I.
F. P. Cox	American Institute of Electrical Engineers	General Electric Co., West Lynn, Mass.
F. A. Kartak	American Institute of Electrical Engineers	Marquette University, Milwaukee, Wis.
O. J. Bushnell	Association of Edison Illuminating Companies	Commonwealth Edison Co., Chicago, Ill.
F. V. Magalhaes	Association of Edison Illuminating Companies	The New York Edison Co., New York City.

Name	*Representation*	*Address*
W. M. BRADSHAW	Electric Power Club*	Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
F. HOLMES	Electric Power Club*	Duncan Electric Mfg. Co., Lafayette, Ind.
R. C. LANPHIER	Electric Power Club*	Sangamo Electric Co., Springfield, Ill.
G. A. SAWIN	Electric Power Club*	Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
F. G. VAUGHEN	Electric Power Club*	General Electric Co., Schenectady, N. Y.
H. KOENIG	Electrical Testing Laboratories	80th St. and East End Ave., New York City
C. H. SHARP	Electrical Testing Laboratories	80th St. and East End Ave., New York City
A. L. PIERCE	International Association of Municipal Electricians	Borough Electric Wks., Wallingford, Conn.
E. D. DOYLE	Leeds & Northrup Co.	4901 Stenton Ave., Philadelphia, Pa.
BURLEIGH CURRIER	National Electric Light Association	Philadelphia Electric Co., Philadelphia, Pa.
ALEXANDER MAXWELL	National Electric Light Association	29 W. 39th St., New York City
W. L. WADSWORTH	National Electric Light Association	Northern States Power Co., Minneapolis, Minn.
C. R. VANNEMAN	New York Public Service Commission	Albany, N. Y.
J. FRANKLIN MEYER	U. S. Bureau of Standards	Washington, D. C.
C. B. HAYDEN	Wisconsin Railroad Commission	Madison, Wis.

The Sectional Committee was formally organized March 14, 1924; J. Franklin Meyer, chairman; E. D. Doyle, secretary, later succeeded by H. Koenig.

The actual revision of the Code was done by four technical subcommittees, as authorized by the Sectional Committee. These subcommittees were:

1. **Acceptance Specifications**: F. V. Magalhaes, *Chairman*, with the following committee: A. J. Allen, W. M. Bradshaw, H. B. Brooks, O. J. Bushnell, C. J. Clarke, C. I. Hall, F. C. Holtz, C. H. Ingalls, A. E. Knowlton and W. H. Pratt.
2. **Installation and Maintenance Methods**: B. Currier, *Chairman*, with the following committee: W. L. Wadsworth, R. C. Fryer, A. S. Albright, W. H. Fellows, A. J. Allen, E. E. Hill, A. G. Turnbull, C. H. Ingalls.
3. **Standards**: E. D. Doyle, *Chairman*, with the following committee: E. E. Hill, A. S. Albright, C. J. Clarke, H. G. Hamann.
4. **Definitions**: J. F. Meyer, *Chairman*, with the following committee: W. H. Fellows, F. A. Kartak, F. C. Holtz, C. H. Sharp.

*Since September 1, 1926, the Apparatus Division of the National Electrical Manufacturers Association.

A preliminary draft was presented at a meeting of the Sectional Committee on April 1, 1926. This draft was approved in general outline, and referred to an editorial committee consisting of Messrs. Meyer, Hill, Pratt, Doyle, Koenig, Currier, Brooks and Fellows. This committee carefully reviewed the draft, agreed upon a standard form and arrangement, and appointed Mr. H. Koenig, the Secretary of the Sectional Committee, to prepare the final draft for the printer. A considerable amount of material appearing in the second edition has been omitted, particularly the circuit diagrams in Section VII, all of Section IX, and the maintenance paragraphs of Section X. The sections or chapters have been renumbered. The omitted material is fully covered in the Handbook for Electrical Metermen, where it now properly belongs.

This code, as revised, was submitted in galley-proof form to all the members of the Sectional Committee for final approval by letter ballot, and it was then formally approved by each of the sponsors. The sponsors, acting jointly, presented the Code to the American Engineering Standards Committee for approval as American Standard, and it was so approved February 20, 1928.

The National Electric Light Association has handled the printing and publishing of this edition.

PREFACE TO THE SECOND EDITION

This edition of the Code for Electricity Meters is a revised and complete compilation of the sections issued separately during the past five years. The revision and arrangement here have been under the supervision of the Meter Committees of the Association of Edison Illuminating Companies and the National Electric Light Association.

Advantage was taken of the printing of the code in complete form to make such revision in the text and to add such new matter as appeared desirable. The Electrical Testing Laboratories joined with the committees in this revision and compilation as they did in the original preparation of the various sections of the code, and this revised edition has their approval.

The Code for Electricity Meters has been generally accepted as a standard of reference for meter practice. Its revision, completion and appearance in one volume enhance its value for this purpose.

The preface, which appeared in the first bound edition of the code in 1910, is printed complete in this edition as a record of the inception and early development of the code.

S. G. RHODES,
Chairman, Meter Committee, Edison Association.
O. J. BUSHNELL,
Chairman, Meter Committee, N. E. L. A.

September, 1912.

PREFACE TO THE FIRST EDITION

(*Reprinted from the* 1910 *Edition of the Meter Code*)

In undertaking two years ago to formulate a Meter Code, it was the ambition of the Meter Committee of the Association of Edison Illuminating Companies to produce a reliable and up-to-date manual covering the many phases of electric meter practice as encountered by all companies, both large and small. It was the committee's belief that such a code, if intelligently prepared, would prove of great value, not alone to those actually engaged in operating meters, but also to those interested in the practice of metering from other standpoints, namely, official, legal, etc. There was also felt an urgent need of a closer agreement between the

manufacturers and the operating companies as to reasonable and satisfactory specifications covering both operation and design.

The development of such a code with the collecting of the very large amount of necessary data was placed in the hands of the Electrical Testing Laboratories of New York, and at the Briarcliff Convention of 1909 there was presented the first issue of the code, covering four sections and representing the first year's work. As a means of increasing the strength and support of the work, and at the same time avoiding duplication of effort along similar lines, it was arranged, with the consent of the Executive Committee of both Associations, to join hands with the Meter Committee of the N. E. L. A. for the further development of the code. The second year's work, therefore, represents the combined efforts of the Meter Committees of the two Associations.

The code to date as here presented includes, with minor revisions and corrections, those sections which have been presented in the reports at the 1909 Edison Convention and the 1910 N. E. L. A. Convention, and also two entirely new sections. It is hoped that it may find its place among the reliable books of reference in the hands of those responsible for, and interested in, the purchase, installation and operation of electric meters.

A considerable amount of ground still remains to be covered, and it is only to be expected that, with changes and improvements in the art, revisions must from time to time become necessary, but it is the intention of the committees to continue the work to its logical conclusion.

While the code is naturally based upon scientific and technical principles, the commercial side of metering has been constantly kept in mind as of very great importance, and it is believed that due consideration has been given to this phase of the problem.

Although the work has been directed very closely by the two committees, the burden of the undertaking has been carried by the Electrical Testing Laboratories, to which full credit should be given.

The committees are indebted to Dr. Clayton H. Sharp for his personal interest and cooperation in the conduct of the work, and to Mr. W. W. Crawford, also of the Laboratories, for the zeal and discrimination which he has displayed in preparing the drafts of the code for the committees' consideration.

The committees would also acknowledge most gratefully the hearty and valuable cooperation of the manufacturing companies and particularly that of Messrs. F. P. Cox and L. T. Robinson of the General Electric Company and Mr. William Bradshaw of the Westinghouse Electric and Manufacturing Company. It is the earnest desire of the committees that the code may prove its value to all of those interested in the precise commercial measurement of electrical energy and may contribute to the advancement of the art.

J. W. COWLES,
Chairman, Meter Committee, Edison Association.
G. A. SAWIN,
Chairman, Meter Committee, N. E. L. A.

METER COMMITTEES
1910

A. E. I. C.	N. E. L. A.
J. W. COWLES, *Chairman*	G. A. SAWIN, *Chairman*
O. J. BUSHNELL	W. E. McCOY
GEO. ROSS GREEN	W. H. FELLOWS
S. G. RHODES	
J. T. HUTCHINGS	

SECTION I

DEFINITIONS

A. Units

1. The measurement of electrical energy for commercial purposes is based upon the international system of electrical units, which, in turn, is based upon the C. G. S. system of electromagnetic units. The values assigned to the various practical units of the international system were adopted by resolution of the International Electrical Congress, held at Chicago in 1893, and were legalized by Act of Congress in 1894 (28 Stat. Ch. 131, p. 102, sec. 1).

The **Units**, in the international system, which are here defined, are those needed in commercial measurements of energy:

2. The **ampere** is the unit of electric current strength. It is the unvarying electric current which, when passed through a solution of nitrate of silver in water, in accordance with standard specifications, deposits silver at the rate of 0.00111800 of a gram per second.

3. The **ohm** is the unit of electrical resistance. It is the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice, 14.4521 grams in mass, of a constant cross-sectional area, and a length of 106.300 centimeters.

4. The **volt** is the unit of electromotive force or of potential difference. It is the electromotive force which, when steadily applied to a conductor the resistance of which is one ohm, will produce a current of one ampere.

5. The **volt** is derived by Ohm's law from the ohm and ampere. Its value is maintained by the aid of the Weston normal cell. The value 1.018300 volts is assigned to the Weston normal cell at 20 deg. cent.

The term "voltage" is used as synonymous with either of the terms "electromotive force" or "potential difference."

6. The **watt** is the unit of power and, expressed in terms of the above units, is defined as the rate at which energy is delivered to a circuit in which a steady current of one ampere is produced by an electromotive force of one volt.

7. A **watthour** is defined as the total or integrated amount of energy delivered in one hour to a circuit in which the steady or average rate at which energy is expended is one watt.

8. A **kilowatt** is 1000 watts.

9. A **kilowatthour** is 1000 watthours.

Charges for energy are based upon the watthour or its multiple, the kilowatthour.

10. An **ampere-hour** is the quantity of electricity passing in one hour through a circuit in which the steady or average value of the current is one ampere.

11. A **horsepower** is equal to 746 watts.

12. A **horsepower-hour** is equal to 746 watthours.

B. Technical Terms

13. What is ordinarily understood as the value of an alternating current is its effective value, i.e., the square root of the mean square of all the values through which the current passes in one cycle. This value is often called the "virtual" value or the "root-mean-square" value.

14. The power expended in a direct-current circuit is equal to the product of the amperes flowing in the circuit by the voltage between the terminals of the circuit.

15. The power expended in an alternating-current circuit at any given instant in the cycle is equal to the product of the voltage and current at that instant. When the voltage and current reverse at the same instant, this product is always positive, and if their wave-forms are alike the power expended is a maximum, and is equal to the product of the effective values of voltage and current. Such a voltage and current are **in phase**. When the term "power expended in an alternating-current circuit" is used, the average value during one cycle is ordinarily meant.

16. Circuits containing certain types of apparatus and known as reactive circuits have the property of storing up a part of the energy supplied to the circuit during a part of each cycle, and restoring this energy to the source during the remainder of the cycle. This causes the reversal of the current to take place at an earlier or a later instant than the reversal of voltage, the current being known then as a **leading** current or a **lagging** current, respectively. During the time when energy is being delivered to the circuit, the product of voltage and current is positive; that is, the voltage and the current have the same sign. When either voltage or current is reversed with respect to the other so that this product is negative, energy is being returned by the circuit to the source, and is then reckoned as negative. The net value of the energy delivered to the circuit per cycle is equal to the difference between the positive and negative values of energy in the two periods. The average value of the power for a given value of voltage and current is then less than the product of the voltage and current (the volt-amperes), and may have any value between the value of the volt-amperes and zero.

17. The ratio between the power, in watts, expended in the circuit and the product of the voltage and current (the volt-amperes) is the power factor of the circuit. The power factor of a circuit is never greater than unity.

18. The power factor of a circuit in which a sine voltage causes a sine current to flow is equal to the cosine of the phase angle between the voltage and the current.

19. The wave form of an alternating voltage or current is the shape of a curve plotted to represent the variation of the voltage or current with respect to time. The sine wave form is standard.

20. When the wave forms of the voltage and current are not the same, the power factor of the circuit will be less than unity, even when the voltage and current reverse at the same instant, due to the fact that, in general, the voltage will be large when the current is small, and *vice-versa,* thus diminishing the average product.

21. The phase angle or phase difference between a sine voltage and a sine current is defined as the number of electrical degrees between the beginning of the cycle of voltage and the beginning of the cycle of current.

C. Systems of Distribution

22. Electric power is distributed in the form of direct current and of single-phase or polyphase alternating current.

23. Direct current and single-phase alternating current are supplied to the consumers' premises either from a two-wire or a three-wire system.

24. A three-wire system is said to be balanced when the currents in the outer wires are equal, the current in the neutral wire is zero, and the voltages between the outer wires and the neutral wire are equal.

25. A polyphase circuit consists of two or more single alternating-current circuits, in which the respective voltages are not in phase. The individual circuits making up the polyphase circuit are referred to as the various phases of the circuit, and the circuit is referred to as two-phase or three-phase, according to the number of phases.

26. A polyphase circuit is said to be balanced when all the receiving circuits have equal voltages, currents and power factors —a condition seldom found in practice.

27. In a two-phase circuit the voltages differ in phase by ninety (90) electrical degrees.

Three forms of two-phase circuit are in use:

(a) The two-phase three-wire circuit.
(b) The two-phase four-wire circuit.
(c) The two-phase five-wire circuit.

28. In a three-phase circuit, the difference in phase between the electromotive forces of any two of the circuits is one hundred and twenty (120) degrees, the same relation applying to the currents when the circuit is balanced. A three-phase circuit might have six line wires, no connection existing between any two of the phases. It is the practice, however, to reduce the number of line wires to four or three by combining them.

The three receiving circuits may be connected to form a triangle, and the three line wires connected to the apices of the triangle. This is the **delta** connection.

One terminal of each of the receiving circuits may be brought to a common point, known as the neutral, and the three line wires connected to the remaining ends of the receiving circuits. This method is the **star** or **Y** connection.

With the generator or transformers connected in star, an additional distributing wire may be taken from the neutral point. This gives three-phase four-wire distribution.

D. Measurement of Power

29. The total power expended in a balanced* two-phase circuit is equal to twice the power expended in one phase of the receiving circuit.

30. The total power expended in a balanced* three-phase circuit is equal to three times the power expended in one phase of the receiving circuit.

31. The following methods are suitable for measurements of power in two-phase circuits:

(a) The power in a two-phase three- or four-wire circuit may be measured by means of two wattmeters, one in each phase. This method is correct for all conditions of load.

(b) The power in a two-phase five-wire circuit may be measured by means of four wattmeters having their current coils connected into each of the four line wires and the voltage coil between the corresponding line wire and a common point, generally the neutral. This method is correct for all conditions of load.

(c) The power expended in a balanced* two-phase circuit may be measured by connecting a wattmeter in one phase of the receiving circuit and multiplying its readings by two.

32. The following methods are suitable for measurements of the power in three-phase circuits:

(a) A wattmeter may be connected in each of the receiving circuits; the sum of the three readings gives the total power. The method is correct for all values of balanced or unbalanced load

*See definition, clause 26.

and at all values of power factor in the receiving circuit, and applies both to three-phase three-wire and to three-phase four-wire circuits.

(b) The total power in a three-phase three-wire circuit may be measured by means of two wattmeters, each having its current coil connected in one of the line wires, and its voltage circuit connected between the line wire in which its current coil is connected and the third line wire. This method does not apply to three-phase four-wire circuits. The algebraic sum of the readings of the two wattmeters indicates the total power expended in the three receiving circuits. The method is correct for any value of balanced or unbalanced load and at any power factor.

(c) The power expended in a balanced* three-phase circuit may be measured by connecting a wattmeter in one phase of the receiving circuit and multiplying its readings by three.

(d) The power expended in a balanced* three-phase circuit may be measured by means of a wattmeter whose current coil is connected in one of the line wires, and whose voltage circuit is connected from the same line wire to the neutral. This method is the same as method (c) in the case of a star-connected circuit. The wattmeter then measures one-third of the total power. The voltage circuit may also be connected to the middle point of an auto-transformer connected between the other two lines, in which case the wattmeter measures one-half the total power. The method is correct at all values of power factor as long as the circuit is balanced.

33. The power factor of a balanced* polyphase circuit is the same as the power factor of any one of the receiving circuits. In the case of an unbalanced polyphase circuit the power factor of each of the receiving circuits should be considered separately.

34. Where the power expended in a polyphase circuit is measured by one wattmeter in each phase, as in the case of the two-phase circuit, or method (a) for a three-phase circuit, the power factor of each circuit is equal to the watts indicated by each wattmeter, divided by the product of the voltage across the voltage circuit of the wattmeter and the current in the current coil of the wattmeter.

35. In the case of a balanced* three-phase circuit, where method (b) is used, the readings of the two wattmeters will be unequal when the power factor is less than unity. The power factor may be determined from the readings of the two wattmeters without measuring the voltage or current of any of the circuits, using the following formula:

$$\tan \Theta = \sqrt{3} \left(\frac{W_1 - W_2}{W_1 + W_2} \right)$$

*See definition, clause 26.

$$\text{or } \cos\theta = \frac{1}{\sqrt{1+3\left(\frac{W_1-W_2}{W_1+W_2}\right)^2}}$$

where θ = angle of lag.

W_1 = reading on wattmeter indicating the larger amount of power.

W_2 = reading on wattmeter indicating the smaller amount of power.

The value of power factor obtained from this relation is correct only when the circuit is balanced.

36. The power factor in a balanced three-phase circuit may also be obtained from wattmeter measurements by methods (c) or (d) by measuring, in addition to the watts, the voltage applied to the voltage circuit of the wattmeter, and the current passing through the current circuit of the wattmeter.

SECTION II

STANDARDS

A. Primary Standards

1. **Final Authority.** The Bureau of Standards of the Department of Commerce at Washington, D. C., is the final authority in the United States for the values of electrical standards, and maintains standards of the legalized practical units of the international system. Other laboratories maintain standards in agreement with those of the Bureau of Standards, and are likewise prepared to measure and certify the values of standards submitted for this purpose. Means are therefore provided for users of electrical standards to maintain them in close agreement with the legalized values.

2. **Equipment.** The standards and instruments for the use of a meter department should be selected to cover all working requirements.

A complete equipment would include the following:

Three or more standard cells. Two sets of standard resistors of the following nominal values: 0.1, 0.01, 0.001 and 0.0001 ohm. One potentiometer of precision type. One volt box (potential divider) with suitable ranges.

One of the 0.001 and one of the 0.0001 ohm resistors should be of large current-carrying capacity, while the remaining two may be of small capacity and serve only as standards of resistance.

One set of the resistors should be reserved as reference standards.

If the standard resistors are sent to a standardizing laboratory for verification at sufficiently frequent intervals, one set only is needed.

Where the expense of a complete equipment of standards would be prohibitive, reference may be made to secondary and primary standards maintained by other users or by a recognized standardizing laboratory.

3. **Certification.** All standards should be provided with proper certificates of accuracy from some standardizing laboratory other than the laboratory of the manufacturer.

The potentiometer and volt box should be subjected to a thorough examination by a standardizing laboratory before acceptance.

The electricity supply company, even though it maintains its own standardizing equipment, should at stated periodic intervals obtain certificates of accuracy of its standards from an independent standardizing laboratory of recognized standing and authority.

4. **Maintenance.** The standard cells should be intercompared weekly, and at least one of them should be sent semi-annually to a standardizing laboratory for verification.*

The working standard resistors should be checked against the reference standard resistors at least semi-annually.

The reference standards of resistance should be verified by a standardizing laboratory at least every two years.

The coils of the potentiometer should be checked against each other at least annually.

The volt box (potential divider) should be checked at least monthly.

B. Secondary Standards

5. **Equipment.** An equipment of secondary standards should include the following:

A laboratory standard direct-current voltmeter, having suitable ranges, capable of being read to 0.05 per cent of the full scale.

A laboratory standard millivoltmeter capable of being read to 0.05 per cent of full scale and suitable shunts for measuring currents within the working range.

A deflection type potentiometer capable of being read to 0.01 per cent of maximum setting of main dial, with suitable volt box (potential divider) and shunts, may be substituted for the laboratory standard voltmeter, millivoltmeter and shunts.

Laboratory standard wattmeters, equally accurate on direct or alternating currents, having ranges with suitable values for all working requirements, capable of being read to 0.05 per cent of full scale.

Standardized voltage and current transformers of suitable ranges.

6. **Maintenance.** Secondary standard instruments should remain permanently in position. They should be compared with the primary standards at least every two weeks, verifying the zero and checking at one point above half scale on each range of the instrument.

A complete check throughout the working range should be made at least each three months, and in addition, whenever an appreciable change is found between the results of successive biweekly checks.

Voltage and current transformers should be sent to a standardizing laboratory at least every two years for the purpose of determining their ratio and phase displacement under working conditions.

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*Shipment of standard cells for certification should preferably be made in mid-spring or early autumn to minimize the effects of exposure to damaging temperatures.

C. Working Standards

7. **Equipment.** Various types and forms of instruments, meters and auxiliaries which may be used as working standards are:

Portable voltmeters which give an indication of two-thirds full scale or more on the voltage which they are to measure.

Portable ammeters or millivoltmeters and shunts of suitable ranges, so that no deflection less than one-quarter of full scale need be used.

Resistors used with voltmeters in the calibrated-resistor method of meter testing which are permanent in value and have a negligible temperature coefficient.

Portable wattmeters of suitable ranges so that no deflections less than one-quarter of full scale need be used.

Rotating standard test meters of suitable range so that they need not operate at less than one-quarter normal full load speed.

Voltage and current transformers of suitable ranges.

8. **Maintenance.** All indicating instruments in use should be checked at least every two weeks, verifying the zero and checking each time the same point between two-thirds and full scale. A check at all cardinal points should be made every two months and a calibration curve supplied, to accompany the instrument. When the latter check indicates a deviation greater than 0.5 per cent from the previous calibration curve or an error of more than one per cent of full scale, the instrument should be readjusted or repaired and recalibrated. All indicating instruments used in testing should be checked directly against the secondary standards.

Checks on calibrated resistors should be made weekly.

Rotating standard test meters should be checked on a commonly used current and voltage range at least every two weeks. A complete check on each current and each voltage coil should be made every three months. The results should be tabulated and supplied to accompany the standard.

D. Horological Standards

9. **Primary Standards.** The primary standard for the measurement of time should be an accurately regulated pendulum clock or an accurate chronometer having a reliable transmitting device by means of which signals can be transmitted or relays operated.

10. **Secondary and Working Standards.** Timing devices more accurate than stop watches are available for use in the laboratory as secondary standards.

Working standards for the measurement of time are generally stop watches. They should be checked daily by comparison with primary or secondary standards.

E. General Remarks

11. Variation in Performance. When the records of performance of any piece of apparatus show an excessive variation between successive tests it should be subjected to a special investigation to ascertain the cause. If the cause of variation cannot be removed, the use of the apparatus should be discontinued.

12. Abnormal Conditions. Whenever any standard is suspected of having been subjected to abnormal conditions or treatment it should be checked regardless of the time which may have elapsed since the last calibration or check.

13. Design and Construction. All instruments should be the best obtainable in design and construction and as free as possible from effects of temperature, stray fields, vibration or other influences. All scales should be accurately laid out and easily readable.

SECTION III

METERING

A. General Definitions

1. An **electricity meter** is an integrating device used for measuring electrical energy or quantity of electricity.

2. A **watthour meter** is an electricity meter that measures and registers electrical energy in watthours or kilowatthours.

Watthour meters are essentially small electric motors, having two circuits, one of which is excited proportionally to the current in the circuit to be measured, and the other proportionally to the voltage in that circuit, so arranged that rotation of the movable element is produced. This rotation is retarded by means of a regulating or braking element, consisting of a disk or cylinder, which moves between the poles of one or more permanent magnets. Eddy currents generated in the disk or cylinder produce a retarding force which varies directly as the speed; therefore, the resultant speed of rotation is proportioned to the watts expended in the circuit, and the total number of revolutions in a given time is a measure of the total watthours expended. The total recorded quantity is read from a register to which the motor shaft is geared.

There are three types of watthour meters in use: the commutator meter, the mercury meter and the induction meter.

3. An **ampere-hour meter** is an electricity meter that registers the quantity of electricity in ampere-hours. Ampere-hour meters are often adjusted to read in kilowatthours at the rated voltage of the circuit.

4. A **demand meter** is a device which records or indicates the maximum average load over any specified time interval, or the average load over a number of equal time intervals.

B. Conditions Influencing the Accuracy of Meters

5. The ideal meter is a frictionless meter, and minimum friction is, therefore, an important desideratum. The retarding torque caused by friction is approximately independent of variations in load. It, therefore, represents a larger percentage of the total torque at light loads than at heavy loads.

6. To compensate for the effect of friction, all modern meters have a compensating device which supplies a constant torque independent of the load upon the meter. This compensating device is excited by the voltage, and its effect is, therefore, variable under variations in voltage.

7. Because of the slight variations in friction at different loads it is impossible to obtain a value of compensation which is absolutely correct at all loads, but the effect of such variations is negligible in well-designed and properly constructed meters.

8. Because of the effect of wear upon the bearings, brushes, commutators, etc., vibration, possible rusting and corrosion, due to dampness, or acid fumes, collection of dust, etc., the friction in a meter installed in service will change with time. This fact constitutes one of the chief reasons for frequent inspections and tests of meters in service.

9. An induction meter gives a correct registration on power factors less than unity only when the phase angle between the eddy currents in the rotating element and the magnetic fields interacting with them to produce the meter torque is the same as the phase angle between the voltage and current in the receiving circuit. The lag adjustment of an induction meter is arranged to produce this condition. When a meter is incorrectly lagged it is subject to errors at low power factors.

10. The effect of variations in frequency on the accuracy of an induction meter at unity power factor is small, and may be either positive or negative. Variations in frequency, however, affect the lag of induction meters, resulting in greater error at power factors other than unity.

11. The effect of temperature changes on a properly constructed meter is small, as the various parts influenced by temperature changes produce effects which tend to neutralize each other.

12. In direct-current commutator meters an external magnetic field adds to, or subtracts from, the field produced by the current coils and produces an error proportional to the resultant change in the effective flux.

Alternating-current meters are generally affected only by alternating fields of the same frequency as the current passing through the meter.

13. The effect of constant external fields may be compensated for by calibrating and adjusting the meter in position.

14. The effect of overloads and short circuits on meters is to alter the magnetization of the drag magnets, to magnetize adjacent masses of iron, and in general to derange the parts, thus affecting the adjustment of the meter. The design of meters has an important effect on the amount of such derangement produced under given conditions.

15. The installation of apparatus on metered circuits in such a way that the apparatus is liable to short circuits or to heavy inrushes of current is detrimental to the accuracy of metering.

C. Permanent Sealing of Watthour Meters

16. On account of the delicate adjustments which meters require, and which are affected by local conditions, it is not advisable that meters should be permanently sealed. To maintain the accuracy at the highest possible value, tests and readjustments of meters in position must be made at frequent intervals, and convenient access to the interior of meters on the part of the employees of the supply company is requisite to this end. Any hindrance to this convenient access can work only to the disadvantage of accurate metering.

D. Methods of Metering

17. A direct-current circuit or a single-phase circuit is metered by means of one watthour meter, the current coil of which should be connected in the ungrounded side of the circuit.

18. In the case of direct-current circuits carrying heavy currents, two or more meters may be used in parallel instead of a single meter capable of carrying the total current, or a shunt type meter may be used.

19. In the case of alternating-current circuits carrying heavy currents or operating at high voltages, transformers are used to reduce the values of current and voltage applied to the meter in a fixed ratio, which brings them within the range of a meter of ordinary construction. Current and voltage transformers should be used in all high-voltage circuits for purposes of insulation, independently of whether the value of current requires their use.

20. A direct-current or a single-phase three-wire system may be metered by one three-wire meter having two current coils, which are connected in the two outer wires of the system, and the voltage circuit of which is connected between the outer wires or between one outer wire and the neutral. The method is correct for all values of balanced or unbalanced current and power factor, provided the voltages remain balanced.

21. Any form of three-wire or polyphase circuit may be metered by treating each receiving circuit separately as a two-wire circuit. This method is correct in all conditions under which single-phase measurement is correct.

22. Any of the methods for the measurement of power in polyphase circuits by means of wattmeters specified in Section I is available for the measurement of energy using watthour meters in the same manner.

23. A polyphase watthour meter consists of either two or three elements having voltage and current circuits corresponding to those of individual meters but affecting a common rotating element. A polyphase meter of the two-element type is used in any

case where two separate meters may be used, and has the advantage that the total energy is recorded upon a single register.

24. The energy in a three-phase four-wire circuit, having balanced voltages, may be metered by a special form of two-element watthour meter wound with split current coils such that the currents in all three circuits pass through the meter. The ordinary two-element meter with special current transformer connections may be used. The voltage circuits are connected to the neutral. Since, however, the condition of voltage balance may not always hold, it is preferable to use three-element meters for this case, when accuracy is important. These meters are independent of voltage unbalancing, except as the individual elements may be affected by deviations from their rated voltage.

25. The energy in a two-phase five-wire circuit may be measured by means of two single-phase three-wire watthour meters or their equivalent.

SECTION IV

SPECIFICATIONS FOR ACCEPTANCE OF TYPES OF ELECTRICITY METERS

PART 1. WATTHOUR METERS

A. General Provisions

1. **Scope.** Only meters of an acceptable or accepted type should be used in the sale of electrical energy to the public, in the interchange of electrical energy between public service companies and in other cases where regulating authorities may require the recording of energy measurements. Many meters are used—and will, for commercial reasons, continue to be used—which, although they do not embody the most recent improvements and developments of the art, are, nevertheless, acceptable in the proper sense of the term. These requirements, therefore, are not intended to define the best meter performance obtainable in new meters.

2. **Definition of Acceptable Meters.** An acceptable meter may be defined broadly as one which registers the electrical energy which passes through it with reliability and commercial accuracy.

3. **Acceptance Tests.** Meters, in order to be recognized as of an acceptable type, shall be capable of conforming to certain requirements specified below, which are intended to determine their reliability and commercial accuracy, insofar as these qualities can be demonstrated by laboratory tests. These requirements are based on the actual conditions of accepted good metering practice of the present day.

4. **Testing Authority.** The acceptability or non-acceptability of types of meters is to be determined by submitting specimens of such types to a duly selected Testing Authority. The Testing Authority shall examine and test the meters in accordance with the specifications and rules herein laid down, and report the results of such examinations and tests and the status of the types of meters as determined thereby.

5. **Adequacy of Testing Authority.** Tests for determining the acceptability of the types of meters under these specifications may be made only in a thoroughly equipped laboratory, having adequate facilities for obtaining steady voltage and current, using instruments of an order of accuracy at least equal to that of the secondary standards described in Section II. These instruments should be checked against high-precision standards before and after the tests or oftener, as required. The tests shall be conducted only by one who has a thorough practical and theoretical knowledge of meters and an adequate training in the making of precision measurements.

B. Types of Watthour Meters Defined

6. (a) **Definition of Type.** Meters are considered to be of the same type if they are produced by the same manufacturer, bear the manufacturer's same type designation, are of the same general design, and have the same relationship of parts. They must be substantially equivalent in the following respects:

1. Arrangement and shape of magnetic circuits
2. Electric circuits and connections
3. Full-load torque
4. Full-load speed
5. Number of magnets
6. Weight of moving element
7. Style of bearings

(b) **Classification Within the Type.** Meters of the same type are classified according to the service for which they are designed, viz:

1. Voltage rating
2. Current rating
3. Frequency
4. Two-, three-, four- or five-wire
5. Single-phase or polyphase

(c) **Acceptance of Type in Whole or Part.** A type of meter may be accepted as a whole, or a restricted class of a type may be accepted and designated as classified in (b) above.

7. **Minor Variations.** Minor variations in the mechanical construction which are not of such character as to affect the electrical operation of the meter, may be permitted in the different meters of the same type.

8. **Classes Requiring Separate Tests:**

(a) Meters of the same type but in different classes with respect to frequency shall be treated as different types for purposes of acceptance tests.

(b) Two- and three-wire meters of the same type are to be treated as different types for purposes of acceptance tests, unless they are in fact similar in all essential details.

(c) Single-phase and polyphase meters of the same type are to be treated for purposes of acceptance tests as if they were of different types.

(d) In the case of meters designed and adjusted to be used with specific current transformers, voltage transformers, shunts or multipliers, these specifications apply to the accuracy of the particular combination.

9. **Special Types.** In the case of a type of meter that comes within the scope of these specifications, but which is of such design

that some of the tests hereinafter specified are inapplicable or cannot be made under the specified conditions, a limited approval may be granted subject to appropriate restrictions.

C. Application to Testing Authority for Acceptance Test

10. **Form of Application.** The application shall state:

(a) Name and address of applicant.

(b) Name and address of manufacturer.

(c) Type designation of the meter by the manufacturer, together with a brief description covering the following points:

1. General description; direct or alternating current; commutator, induction or mercury; giving any special features of construction, or unusual principles of operation.
2. Shape and dimensions; round, square or rectangular; dimensions; height, width, depth, diameter.
3. Cover; shape (round, square, rectangular), material (metal, glass), finish, windows, method of support.
4. Base; how constructed, material, what it supports.
5. Frame; how constructed, material, what it supports.
6. Magnets; number and arrangement.
7. Circuits; description and diagram of voltage and current circuits.
8. Terminals; number, front or back connected, location of terminal chamber.
9. Moving element; complete description, including weight and torque.
10. Bearings; what kind and how supported.
11. Register; shape, finish, dials, unit of registration, meaning of register ratio.
12. Adjustments, description of; for light load, full load, power factor, balance of elements.
13. Marked ratings; phase, frequency, voltage and current.
14. Shunts, resistors, reactors, transformers and other associated apparatus.

11. **Specimens Submitted to be Representative of Type.** In making application for the test, adequate evidence shall be furnished to show that the specimens submitted are, in fact, representative of the whole type, or class of the type, and that they actually represent the average commercial product of the type submitted for acceptance.

12. **Number to be Submitted:**

(a) Not less than ten meters shall be taken as specimens of each type submitted for the tests, to determine the acceptability of the type, except in the case of meters of unusual or little used types, when a smaller number may be taken as being representative of the type.

(b) When the specimens representing a given type include different classifications with respect to the marked current and voltage rating, there shall be not less than two meters of each of the representative current ratings for each class, all of these to be preferably of the same voltage rating. There shall be not less than two meters of each voltage rating, all of which should be preferably of the same current rating.

13. **Additional Meters for Replacements.** When practicable, meters submitted for acceptance tests shall be accompanied by a sufficient additional number of each type, from which meters found defective or those accidentally damaged in test may be replaced.

14. **Manufacturer to be Notified of Test.** When meters are submitted for test the manufacturer of the meter shall, where practicable, be duly notified of the place and time of test, and shall be privileged to have representatives present during the adjustment and test of the meters.

These representatives, as well as the representatives of the applicant, may present any facts or instructions designed to insure the use of proper methods and accurate results in adjusting and testing the particular type of meters under test. When no protests are registered by such representatives, it may be assumed that the adjustments, instruments and methods of test meet with their approval.

15. **Final Arbiter.** The Testing Authority shall be the final arbiter.

D. Specifications for Design and Construction

16. **Scope of the Specifications.** Specifications for design and construction are expressed in this code only in terms corresponding to the requirements to be met in practice.

17. **Type Designation and Identification.** Each meter shall be designated by type, and given a serial number by the manufacturer to identify it as an individual. The serial number and type designation shall be legibly marked on the base, nameplate or frame of each meter, in such a manner as to be visible when the meter is in service. The register ratio shall be marked on a permanent part of the register.

18. **Fixed and Adjustable Parts.** All fixed parts shall be held securely in a permanent relationship. All adjustable parts shall be so constructed that they can be readily released, easily moved and securely fastened in place without damage to the parts or to the meter.

19. **Accuracy and Range of Adjustment.** The meter shall be designed to facilitate testing, installing, reading and repairing.

Such connections and parts as require adjustment in service shall be easily accessible after removing the cover. The adjustments of the meter shall be such as to be capable of bringing the registration within one per cent (1%) of accuracy at ten per cent (10%) and one hundred per cent (100%) of rated current (at unity power factor in the case of alternating-current meters). The range of each adjustment shall be sufficient to permit the meter to be adjusted to register correctly under all ordinary conditions met with in service.

20. **Sealing.** The meter shall be so designed that the cover and terminal chambers can be securely sealed.

21. **Cover.** The cover of the meter shall be sufficiently strong to withstand all ordinary usage. It shall be dustproof and designed to prevent access to the interior without destroying the seal.

22. **Terminals.** The terminals of the meter shall be so arranged that the possibility of short circuits in removing or replacing the cover, making connections and adjusting the meter, is minimized.

23. **Construction and Workmanship.** The meter shall be substantially constructed, in a workmanlike manner, of good material.

24. **Weight of Moving Element.** The moving element shall be as light as practicable without the sacrifice of other desirable features, thus minimizing wear and the possibility of damage to the bearings.

25. **Full-Load Torque Ratios.** The ratio of the full-load torque to the friction at the speed corresponding to full load shall be high, thus minimizing the liability of change in the accuracy of the meter due to changes in friction.

E. Preliminary Adjustments and Preparation of Meters for Acceptance Tests

26. **Initial Inspection.** On arrival at the place of test the meters shall be inspected for damage received in transportation. Meters which are found on inspection to be defective may be replaced from the meters held in reserve.

27. **Calibration and Adjustments.** After meters are set up for test a representative of the applicant or manufacturer shall be allowed to calibrate them. He may use any standard method of adjustment for the given type, but make no structural changes in the meters, nor use any method of adjustment which cannot be regularly applied in ordinary commercial use. In case defects are found in any of the meters during this adjustment, which were not discovered in the preliminary inspection, the defective meter may be replaced at the discretion of the Testing Authority. The defect

in the meter shall, however, be of a definite and specific nature, and be capable of ready detection by other methods than that of an accuracy test. Any damage or defect, of the character specified above, which can be repaired by the replacement of an interchangeable part, may be so repaired without replacing the given meter.

28. **Preliminary Tests by Applicant.** Before beginning the series of official tests on the meters, the representatives of the applicant or manufacturer, interested in having the type accepted, shall be allowed to test and adjust the meters under any or all of the conditions to which they are to be subjected in the acceptance tests. Complete facilities for this purpose shall be furnished by the Testing Authority. A reasonable amount of time, in the judgment of the Testing Authority, shall be allowed for the above tests and adjustments. A reasonable amount of time may be defined as sufficient time for going through all of the acceptance tests on each of the meters once only, with reasonable allowance for rechecking of points and readjustments of the meters. At this time the applicant may withdraw all the meters of any type.

29. **Formal Delivery for Test.** When the representative adjusting the meters pronounces them ready, or when the Testing Authority considers that sufficient time has been allowed, the meters shall be formally turned over to the Testing Authority for test. No interested representative shall be allowed access to the meters thereafter, and no further readjustments or withdrawals shall be made until all tests specified have been completed. Interested representatives, however, may witness the tests, and shall be furnished reasonable facilities for obtaining information as to the conduct and results of the tests.

30. **Preliminary Adjustment by Testing Authority.** The preliminary adjustment of the meter may, at the request of the applicant, be made by the Testing Authority, who shall then, in this part of the work, act in the interest of the applicant desiring the acceptance of the type and shall observe all the rules laid down respecting the privileges of said applicant.

F. Definitions, Conditions of Test

31. **Percentage of Accuracy.** The percentage of accuracy of a meter is the ratio, expressed as a percentage, of the registration in a given time to the true kilowatthours, and is commonly referred to as the "accuracy" or "percentage accuracy" of the meter.

32. **Percentage Error.** The percentage error of a meter is the difference between its percentage of accuracy and one hundred per cent (100%). A meter whose percentage of accuracy is ninety-five per cent (95%) is said to be five per cent (5%) slow, or its

error is minus five per cent (— 5%). A meter whose percentage of accuracy is one hundred and five per cent (105%) is five per cent (5%) fast, or its error is plus five per cent (+5%).

33. **Reference Performance.** The reference performance of a meter as established for each test furnishes a means of comparing the performance of the meter under normal (reference) and test conditions. The variations from reference performance accuracy are known as deviations from reference performance.

34. **Creep.** For the purpose of acceptance tests, a meter is considered to creep if, with the load wires removed, and with test voltage applied to the voltage circuit of the meter, the moving element rotates continuously, making at least one complete rotation in fifteen minutes.

35. **Covers and Registers:**

(a) Meter covers, where possible, shall be in place during all tests and may be sealed.

(b) The registers of the meters shall be in train during the tests.

36. **Electrical Connections for Three-wire and Polyphase Meters:**

(a) Three-wire meters shall be tested with their current circuits in series, except when the equality of the circuits is being checked. The term "current circuit" is understood to mean the path of the main current through the meter, and with this understanding it applies to mercury meters.

(b) Polyphase meters subjected to single-phase tests shall be tested with their current circuits in series and their voltage circuits in parallel, except when otherwise specified.

37. **Standard Temperature:**

(a) The average room temperature during the adjustment of the meters shall be taken as the standard temperature for the subsequent tests. The standard temperature should not be below 15 deg. cent., nor above 30 deg. cent.

(b) In case tests are made when the room temperature differs from the standard temperature, a suitable allowance may be made in the results for variations caused thereby.

38. **Calibration Voltage:**

(a) The voltage applied during the adjustments of the meters shall be known as the calibration voltage.

(b) The calibration voltage shall be the marked rated voltage, or the mean rated voltage of the meters, when the meters are to be used on circuits of normal voltage not less than ninety-five per cent (95%) nor greater than one hundred and five per cent (105%) of the marked rated voltage, or mean rated voltage of the meters.

(c) In case normal voltages of the circuits on which the meters are to be used are less than ninety-five per cent (95%) or more than one hundred and five per cent (105%) of the marked rated voltage or mean rated voltage of the meters, calibration voltage shall be the average of the normal voltages of the circuits on which the meters are to be used.

39. **Interim Conditions.** The official tests shall be begun after all of the conditions have been complied with, and not less than one hour nor more than two hours after the adjustment of the meters has been completed. In the interval, the meters shall be operated at calibration voltage and approximately ten per cent (10%) of rated current.

40. **Tests to be Applied to All Meters.** Each meter shall be subjected to the tests as specified, excepting meters which are a modification of a type that has already been subjected to the tests. The Testing Authority may determine to which of the specified tests such meters shall be subjected.

41. **Order of Conducting Tests:**

(a) The tests and the items of each test shall be conducted in the order given.

(b) After each change in voltage, or load, a sufficient time interval shall be allowed for the meter to come to a stable condition before making the next observation or test.

42. **Alternating-Current Tests.** All alternating-current tests shall be conducted on a circuit supplied by a generator giving a close approximation to a simple alternating wave as defined in the Standards of the American Institute of Electrical Engineers.

G. Rules Governing the Acceptance and Rejection of Types

43. **Allowable Number of Replacements.** If, during the test of a meter type, thirty per cent (30%) or more of the meters have to be replaced, due to physical defects which become apparent during the tests, the type shall be rejected.

44. **Tolerances in Accuracy Requirements.** In no case shall a meter be considered to fall outside of the specified limits in any item depending upon a determination of the accuracy of the meter, unless the limit is exceeded by the amount of one-quarter per cent (0.25%), which is a value of testing error assigned to cover possible errors in the standards employed and in the observations.

45. **Variations in Accuracy During Tests.** The results of all the tests on each meter made under similar and comparable conditions at ten per cent (10%) and one hundred per cent (100%) of rated current in the following clauses shall be collected and averaged separately.

Items No. 1 *and* 2. In an acceptable meter, the mean of the deviations, disregarding the sign, of the individual accuracies at either load from the average accuracy at the corresponding load shall not exceed two per cent (2%).

46. **Basis of Acceptable Performance.** A type of meter shall be considered to pass and be accepted under these specifications when each of the following requirements is satisfied:

(a) In the tests made on ten meters, not over three meters shall fail in a given item of a given clause.

(b) No individual meter shall fail in more than five items.

(c) In the tests made on ten meters the total number of failures, including all the meters and all the items of each clause, shall not exceed twenty.

(d) In any of the clauses, where tests on fewer than ten meters are permitted, no meter shall fail in any item in such tests. At the request, however, of the applicant, or when in the judgment of the Testing Authority the results on fewer than ten meters are unreliable, the tests may be repeated on ten meters, and the results included with the remainder of the clauses for treatment under requirements (a), (b) and (c).

(e) The items of Test No. 1 on polyphase meters—Independence of Elements—shall not be included in the summaries.

H. Specifications for the Testing of Direct-Current Watthour Meters

47. **Test No. 1. Initial Performance.** *Test conditions:* The test shall be made at calibration voltage.

Item No. 1. The meter shall not creep (as defined in Section IV-34) at one hundred and ten per cent (110%) of calibration voltage.

Items No. 2 *to* 8, *inclusive.* The initial performance of the meter shall not deviate in per cent from one hundred per cent (100%) by an amount exceeding that specified below:

Item No.		Per Cent of Rated Current	Maximum Deviation in Per Cent from 100%
2	Shall run continuously....	2	.....
3	....	5	±6.0
4	....	10	±3.0
5	....	20	±2.0
6	....	50	±2.0
7	....	100	±2.0
8	....	150	±2.0

Item No. 9. The difference between the performance at ten per cent (10%) rated current and that at one hundred per cent (100%) rated current shall not exceed three per cent (3%).

48. **Test No. 2. Effect of Variation of Voltage.** *Test conditions:* The test shall be made at the various values of watts and voltages given below:

Items No. 1 *to* 8, *inclusive.* The effect of variation of voltage upon the performance of a meter carrying constant load in watts shall not exceed that specified below, provided that only meters with a voltage rating extending over a range greater than fifteen per cent (15%) of calibration voltage shall be subjected to the last four items of this test.

Item No.	Per Cent Rated Watts	Maximum Deviation in Per Cent from Reference Performance
1. Ninety per cent (90%) of calibration voltage...	10	±5.0
2. Ninety per cent (90%) of calibration voltage...	100	±3.0
Reference performance — one hundred per cent (100%) of calibration voltage—for items 1, 3, 5 and 7....................................	10	.....
Reference performance — one hundred per cent (100%) of calibration voltage—for items 2, 4, 6 and 8....................................	100	.....
3. One hundred and ten per cent (110%) of calibration voltage...........................	10	±5.0
4. One hundred and ten per cent (110%) of calibration voltage...........................	100	±3.0
5. Ninety-five per cent (95%) of minimum marked voltage..................................	10	±5.0
6. Ninety-five per cent (95%) of minimum marked voltage..................................	100	±3.0
7. One hundred and five per cent (105%) of maximum marked voltage......................	10	±5.0
8. One hundred and five per cent (105%) of maximum marked voltage......................	100	±3.0

49. **Test No. 3. Equality of Current Circuits in Three-Wire Meters.** *Test conditions:* The test shall be made at calibration voltage.

Items No. 1 *to* 4, *inclusive.* The change produced in the registration of a meter by using only one current circuit as compared

with that when both current circuits are used shall not exceed that specified below:

Item No.	Connections	Per Cent of Rated Current	Maximum Deviation in Per Cent from Reference Performance
Reference performance for items 1 and 2	Both circuits	10	.....
1.	Circuit A only	20	±2.0
2.	Circuit B only	20	±2.0
Reference performance for items 3 and 4	Both circuits	50	.....
3.	Circuit A only	100	±2.0
4.	Circuit B only	100	±2.0

50. **Test No. 4. Effect of External Magnetic Field.** *Test conditions:* The test shall be made at calibration voltage.

Item No. 1. The change produced in the performance of a meter at twenty per cent (20%) of rated current by the application in the manner stated of an external magnetic field of the value given below shall not exceed two and one-half per cent (2.5%).

An approximately uniform magnetic field of 0.25 gauss shall be applied to one of the meters submitted, in such a direction as to have the maximum effect upon the registration of the meter.

Item No.	Per Cent Rated Current	Magnetic Field in Gauss	Maximum Deviation in Per Cent from Reference Performance
Reference performance	20	....	.....
1.	20	0.25	±2.5

Note: A field of approximately 0.25 gauss may be produced and applied as follows:

(a) Wind two coils of 4 turns each on the edges of two wooden disks, 50 cm. in radius.

(b) Place the disks 50 cm. apart in a vertical position.

(c) Pass 3.5 amperes through the coils, connected in series so that the direction of winding is the same in passing from one to the other.

(d) Place the coils so that the central uniform part of their field produces a maximum effect upon the performance of the meter.

51. Test No. 5. Effect of Variation of Temperature. *Test conditions:*

(a) The test shall be made at calibration voltage and shall be applied to not less than three meters, excepting that when less than five meters are submitted as specimens, the test may be applied to less than three meters.

(b) The per cent difference in the performance of the meter at the higher temperature from that at the lower temperature, divided by the difference in temperature, is the average temperature coefficient.

Items No. 1 *and* 2. Meters without external shunts. The average temperature coefficient shall not exceed two-tenths per cent (0.2%) per deg. cent. at either ten per cent (10%) or one hundred per cent (100%) rated current for meters without external shunts.

The meter shall be placed in a space having a temperature of approximately 20 deg. cent., or room temperature as specified in Section IV-37, and allowed to stand for not less than two hours with the voltage circuit of the meter energized. A load of ten per cent (10%) of the rated current shall then be applied, and after running for one hour the performance of the meter shall be determined at this load. A load of one hundred per cent (100%) of the rated current of the meter shall then be applied for one hour and the performance determined at this load. These operations shall be repeated in the same order at a temperature approximately 20 deg. cent. higher, and the temperature coefficient at each load calculated.

Items No. 3 *and* 4. Meters with external shunts. The temperature coefficient shall not exceed two-tenths per cent (0.2%) per deg. cent. at either ten per cent (10%) or one hundred per cent (100%) of rated current for meters with external shunts. The meter with its shunt and connecting leads shall be tested at ten per cent (10%) and one hundred per cent (100%) loads at two temperatures as specified under Items 1 and 2.

Items No. 5, 6, 7 *and* 8. Meters with external shunts and connecting leads more than five feet in length. The change in performance at either ten per cent (10%) or at one hundred per cent (100%) of rated current shall not exceed two-tenths per cent (0.2%) per deg. cent. inequality of temperature between meter and shunt.

For meters having external shunts with connecting leads more than five feet in length the effect of unequal heating of the shunt and meter shall be determined in a manner similar to the determination of temperature coefficient in Items 1 and 2 above, first, with meter, shunt, and leads, in a space at approximately 20 deg. cent. to be used as reference performances at ten per cent (10%) and one hundred per cent (100%) load; second, (Items 5 and 6)

with the meter and one-half the length of the leads in a space at approximately 20 deg. cent., the shunt and the other half of the leads in a space approximately 20 deg. cent. higher; and, third, (Items 7 and 8) with the meter and one-half the length of the leads in a space at approximately 40 deg. cent. and the shunt and other half of the leads in a space approximately at 20 deg. cent. lower.

Item No.	Per Cent Rated Current Applied For One Hour	Ambient Temperature	Temperature Coefficient Per Cent per °C.
Ref. performance for items 1, 3, 5 and 7.	10	Room temp. or approx. 20° C.	...
Ref. performance for items 2, 4, 6 and 8.	100	Room temp. or approx. 20° C.	...
1 (without external shunt)..........	10	Approx. 20° C. higher than room temperature	0.2
2 (without external shunt)..........	100	Approx. 20° C. higher than room temperature	0.2
3 (with external shunt)..........	10	Approx. 20° C. higher than room temperature	0.2
4 (with external shunt)..........	100	Approx. 20° C. higher than room temperature	0.2
5 External shunt with leads more than 5 ft. long	10	Meter at room temp., shunt 20° C. higher	0.2
6 External shunt with leads more than 5 ft. long	100	Meter at room temp., shunt 20° C. higher	0.2
7 External shunt with leads more than 5 ft. long	10	Meter at 40°C., shunt at room temperature	0.2
8 External shunt with leads more than 5 ft. long	100	Meter at 40°C., shunt at room temperature	0.2

52. **Test No. 6. Effect of Temporary Overloads.** *Test conditions:* The test shall be made at calibration voltage and shall be applied to not less than three meters, excepting that when less than five meters are submitted as specimens, the test may be applied to less than three meters.

Items No. 1 *and* 2. The effect of temporary overload upon the registration of meters of less than 600 amperes rating shall not exceed the values given below. A temporary load of four times the rated current of the meter shall be applied three times to each meter under test, the duration of each overload being approximately two seconds. Each meter shall be tested with ten per cent (10%) of rated current and one hundred per cent (100%) of rated current before the application of the overload and again afterward.

The per cent deviation in performance due to the temporary overload shall not exceed five per cent (5%) at ten per cent

(10%) of rated current (Item 1), nor exceed three per cent (3%) at one hundred per cent (100%) of rated current (Item 2).

Item No.	Per Cent Rated Current	Number of Applications	Duration of Application in Seconds	Maximum Deviation in Per Cent from Reference Performance	
				10% Current	100% Current
Reference performance item No. 1 before and after overload........	10	....	....	....	....
Reference performance item No. 2 before and after overload........	100	....	....	....	....
Item No. 1............	400	3	2	±5.0	....
Item No. 2............	400	3	2	....	±3.0

Meters of over 600 amperes rating will be submitted by the testing authority to such tests as are considered necessary.

53. **Test No. 7. Voltage Drop or Watt Loss in Current Circuits.** *Test Conditions:* The voltage drop or the watt loss in the current circuit of each meter shall be measured at one hundred per cent (100%) of rated current. Rated direct current shall be passed through the current circuit and the drop of potential measured with a millivoltmeter or other suitable instrument. The watt loss can then be calculated.

Item No. 1. In meters of 25 amperes rating or less the loss shall not exceed 15 watts.

In meters of more than 25 amperes rating the drop shall not exceed 0.4 volt.

In three-wire meters the voltage drop or the watt loss applies to each current circuit separately.

I. Specifications for the Testing of Single-Phase Watthour Meters (of rated frequencies—20-70 cycles)

54. **Test No. 1. Initial Performance.** *Test conditions:* The test shall be made at calibration voltage, rated frequency and unity power factor.

Item No. 1. The meter shall not creep, as defined in Section IV-34, at one hundred and ten per cent (110%) of calibration voltage.

Items No. 2 to 8, inclusive. The initial performance of the meter shall not deviate from one hundred per cent (100%) by an amount exceeding that specified below:

Item No.		Per Cent Rated Current	Maximum Deviation in Per Cent from 100%
2	shall run continuously........	2	.....
3	....	5	±3.0
4	....	10	±1.5
5	....	20	±2.0
6	....	50	±2.0
7	....	100	±1.5
8	....	150	±2.5

Item No. 9. The difference in the performance at ten per cent (10%) rated current from that at one hundred per cent (100%) rated current shall not exceed two per cent (2%).

55. **Test No. 2. Effect of Variation of Power Factor.** *Test conditions:* The test shall be made at calibration voltage and rated frequency. In the case of a polyphase meter, tested with single-phase load, the test shall be made on each current element separately, but with the voltage circuits of both elements energized.

Items No. 1 *to* 4, *inclusive.* The effect of variation of power factor upon the performance of a meter shall not exceed that specified below.

Item No.	Per Cent Rated Current	Per Cent Power Factor	Maximum Deviation in Per Cent from Reference Performance
Reference performance items 1 and 2......................	10	100	.....
1	13	75 lagging	±1.5
2	20	50 lagging	±3.0
Reference performance items 3 and 4......................	100	100	.....
3	100	75 lagging	±1.5
4	100	50 lagging	±3.0

56. **Test No. 3. Effect of Variation of Voltage.** *Test conditions:* The test shall be made at rated frequency and unity power factor.

Items No. 1 *to* 8, *inclusive.* The effect of variation of voltage upon the performance of a meter carrying constant loads in watts shall not exceed that specified below, provided that only meters

with a voltage rating extending over a range greater than fifteen per cent (15%) of calibration voltage shall be subjected to the last four items of the test.

Item No.	Per Cent Rated Watts	Maximum Deviation in Per Cent from Reference Performance
1. Ninety per cent (90%) of calibration voltage...	10	±2.0
2. Ninety per cent (90%) of calibration voltage...	100	±1.5
Reference performance—one hundred per cent (100%) of calibration voltage—for items 1, 3, 5 and 7	10	.....
Reference performance—one hundred per cent (100%) of calibration voltage—for items 2, 4, 6 and 8	100	.....
3. One hundred and ten per cent (110%) of calibration voltage	10	±2.0
4. One hundred and ten per cent (110%) of calibration voltage	100	±1.5
5. Ninety-five per cent (95%) of minimum marked voltage	10	±2.0
6. Ninety-five per cent (95%) of minimum marked voltage	100	±1.5
7. One hundred and five per cent (105%) of maximum marked voltage	10	±2.0
8. One hundred and five per cent (105%) of maximum marked voltage	100	±1.5

57. **Test No. 4. Effect of Variation of Frequency.** *Test conditions:* The test shall be made at calibration voltage and unity power factor.

Items No. 1 *to* 4, *inclusive.* The effect of variation of frequency upon the registration of a meter carrying constant load shall not exceed that specified below:

Item No.	Per Cent Rated Current	Per Cent Rated Frequency	Maximum Deviation in Per Cent from Reference Performance
Reference performance items 1 and 3	10	100	.....
Reference performance items 2 and 4	100	100	.....
1	10	95	±1.5
2	100	95	±1.5
3	10	105	±1.5
4	100	105	±1.5

58. **Test No. 5. Equality of Current Circuits in Three-Wire Meters.** *Test conditions:* The test shall be made at calibration voltage, rated frequency and unity power factor. In case of polyphase meters tested under these single-phase specifications, the voltage circuits of both elements shall be energized throughout the test.

Items No. 1 *to* 4, *inclusive.* The change produced in the performance of a meter by using only one current circuit as compared with that when both current circuits are used shall not exceed that specified below:

Item No.	Connections	Per Cent Rated Current	Maximum Deviation in Per Cent from Reference Performance
Reference performance items 1 and 2	Both circuits	10	.....
1	Circuit A only	20	±2.0
2	Circuit B only	20	±2.0
Reference performance items 3 and 4	Both circuits	50	.....
3	Circuit A only	100	±2.0
4	Circuit B only	100	±2.0

59. **Test No. 6. Effect of External Magnetic Field.** *Test conditions:* The test shall be made at calibration voltage, rated frequency and unity power factor.

The change produced in the performance of a meter at ten per cent (10%) of rated current by the application of an external magnetic field in the manner stated, shall not exceed one per cent (1%). One of the meters shall be subjected to an alternating magnetic field of the same frequency as that of the testing current and produced by a straight conductor six feet long, with return leads arranged to form a rectangle six feet square. A current of 50 amperes in phase with the voltage applied to the meter shall be passed through this conductor. The return leads of the conductor shall be so arranged that the loop which they form does not surround or include the meter.

Place the straight six-foot conductor in each of the following positions:

Item No. 1. Behind the test board in a horizontal position and parallel to the back of the meter. The middle of the conductor shall be fifteen inches directly behind and on a level with the

center of the moving element. The loop shall be in a horizontal plane perpendicular to the test board.

Item No. 2. Directly behind the center line of the meter in a vertical position. The middle of the conductor shall be fifteen inches directly behind and on a level with the center of the moving element. The loop shall be in a vertical plane perpendicular to the test board.

Item No. 3. Vertically at the same distance in front of the test board as the center of the moving element. The middle of the conductor shall be on a level with the center of the moving element and fifteen inches to the right or left. The loop shall be in a vertical plane parallel to the test board.

Item No.	Per Cent Rated Current	Position of Conductor	Amperes in Conductor	Maximum Deviation in Per Cent from Reference Performance
Reference performance...	10	....	....	.....
1	10	See item 1 above	50	±1.0
2	10	See item 2 above	50	±1.0
3	10	See item 3 above	50	±1.0

60. **Test No. 7. Effect of Variation of Temperature.** *Test conditions:*

(a) The test shall be made at calibration voltage, rated frequency and unity power factor, and shall be applied to three meters, excepting that when less than five meters are submitted as specimens, the test may be applied to less than three meters.

(b) The per cent difference in the performance of the meter at the higher temperature from that at the lower temperature, divided by the difference in temperature, is the average temperature coefficient. The average temperature coefficient shall not exceed twelve-hundredths per cent (0.12%) per deg. cent. at either ten per cent (10%) or one hundred per cent (100%) of rated current. The meter shall be placed in a space having a temperature of approximately 20 deg. cent., or room temperature, as specified in Section IV-37, and allowed to stand for not less than two hours with the voltage circuit of the meter energized. A load of ten per cent (10%) of the rated current shall then be applied, and after running for one hour, the meter shall be tested at this load. A load of one hundred per cent (100%) of rated current shall then be applied for one hour and

the meter again tested at this load. These operations shall be repeated in the same order at a temperature approximately 20 deg. cent. higher.

Item No.	Per Cent Rated Current Applied for One Hour Before Test	Ambient Temperature	Temperature Coefficient Per Cent per °C
Reference performance	10	Room or approx. 20° C.	....
Reference performance	100	Room or approx. 20° C.	....
1	10	20° C. higher than room	0.12
2	100	20° C. higher than room	0.12

61. **Test No. 8. Effect of Temporary Overloads.** *Test conditions:* The test shall be made at calibration voltage, rated frequency and unity power factor, and shall be applied to not less than three meters, excepting that when less than five meters are submitted as specimens, the test may be applied to less than three meters.

The effect of temporary overloads upon the performance of the meter shall not exceed one per cent (1%) at either ten per cent (10%) of rated current (Item 1), or one hundred per cent (100%) of rated current (Item 2). A temporary load of four times the rated current shall be applied three times to each meter under test, the duration of each overload being approximately two seconds. The overload current shall be approximately in phase with the voltage applied to the voltage circuit of the meters.

Each meter shall be tested with ten per cent (10%) of rated current and one hundred per cent (100%) of rated current, both before and after the application of the overload.

Item No.	Per Cent Rated Current	Number of Applications	Duration of Application in Seconds	Maximum Deviation in Per Cent from Reference Performance	
				10% Current	100% Current
Reference performance	10	....	....	.....	.....
Reference performance	100	....	....	.....	.....
1	400	3	2	±1.0	.....
2	400	3	2	.....	±1.0

62. **Test No. 9. Voltage Drop or Watt Loss in Current Circuits.** *Test conditions:* The voltage drop or the watt loss in the current circuit of each meter shall be measured at one hundred per cent (100%) of rated alternating current at rated frequency; or, in the discretion of the Testing Authority, at one hundred per cent (100%) of rated direct current. In meters of 25 amperes rating or less, the loss shall not exceed 5 watts.

In meters of more than 25 amperes rating, the drop shall not exceed 0.15 volt.

In three-wire meters, the voltage drop or the watt loss applies to each current circuit separately.

J. Specifications for the Testing of Polyphase Watthour Meters (of rated frequencies—20-70 cycles)

63. **General Conditions.**

(a) The specifications in this section apply to types of polyphase meters having two independent elements, each element having one current circuit and one voltage circuit. The specifications, however, may be applied as far as applicable to any other types of polyphase meters, provided that equivalent tests may be substituted by the testing authority for such of the tests as are not applicable, or which cannot be made under the conditions specified.

(b) In case the preliminary adjustment of the meter is made upon a polyphase load, the relation of the phases as applied to the elements used in the preliminary adjustment shall be maintained in all subsequent tests.

64. **Test No. 1. Independence of Elements.** *Test conditions:* The test shall be made on a two-phase circuit at calibration voltage, rated frequency, and unity power factor in the loaded element.

Throughout the test the voltage and current windings of one element (element A) of the meter shall be connected to phase 1 of the two-phase circuit. The other element (element B) shall be connected as indicated below. In the current tests, under items 5 to 8, inclusive, the currents in both elements shall be equal.

Items No. 1 to 8, inclusive. The performance of the meter under test conditions specified below shall not deviate from the refer-

ence performance at the corresponding load by an amount exceeding that specified below:

Item No.	Connections of Element B: Voltage Circuit	Connections of Element B: Current Circuit	Maximum Deviation in Per Cent from Reference Performance: 20% Rated Current on Element A	Maximum Deviation in Per Cent from Reference Performance: 100% Rated Current on Element A
Reference performance..	Phase I direct	Not connected	.....	.....
1	Phase I reversed	Not connected	±1.0	.....
2	Phase I reversed	Not connected	.....	±1.0
Reference performance..	Phase II direct	Not connected	.....	.....
3	Phase II reversed	Not connected	±1.0	.....
4	Phase II reversed	Not connected	.....	±1.0
Reference performance..	Not connected	Phase I direct	.....	.....
5	Not connected	Phase I reversed	±1.0	.....
6	Not connected	Phase I reversed	.....	±1.0
Reference performance..	Not connected	Phase II direct	.....	.....
7	Not connected	Phase II reversed	±1.0	.....
8	Not connected	Phase II reversed	.....	±1.0

65. **Procedure Subsequent to Test No. 1.**

(a) If each meter of a given type conforms to each of the requirements of the test for independence of elements, the further tests for acceptability shall be made on a single-phase circuit, using the specifications laid down for a single-phase three-wire meter.

(b) In case one meter fails in any of the requirements of the test for independence of elements, the acceptance tests of the type to which such meters belong shall be made on a polyphase circuit according to the specifications following. A type conforming to the requirements of the polyphase test will be accepted, subject to the provision that meters of the given type shall, in service, be calibrated and tested on a polyphase circuit of the same character as that on which it is used.

(c) The two-phase test is adopted as a standard for the

purpose of acceptance tests only, and is to be used in the case of all meters, except such as are designed or designated as three-phase meters, which shall be submitted to the corresponding three-phase tests.

(d) In the case of a three-phase four-wire meter, all three elements shall be subjected to requirements as to equality similar to those specified for a meter having two elements.

66. **Test No. 2. Initial Performance—Both Elements in Circuit.** *Test conditions:* The test shall be made at calibration voltage, rated frequency and unity power factor in the testing circuit. Each meter shall be tested with a balanced polyphase load, both elements being in circuit.

Item No. 1: No meter shall creep with one hundred and ten per cent (110%) of calibration voltage applied, with voltage circuits connected to a symmetrical polyphase voltage.

Items No. 2 *to* 8, *inclusive:* The initial performance of the meter shall not deviate from one hundred per cent (100%) by an amount exceeding that specified below:

Item No.	Per Cent Rated Current	Maximum Deviation in Per Cent from 100%
2 Shall run continuously	2	.....
3	5	±3.0
4	10	±1.5
5	20	±2.0
6	50	±2.0
7	100	±1.5
8	150	±2.5

The difference in performance at ten per cent (10%) rated current from that at one hundred per cent (100%) rated current shall not exceed two per cent (2%).

67. **Test No. 3. Equality of Elements.** *Test conditions:* The test shall be made at calibration voltage and rated frequency. Both voltage circuits of each meter shall be energized continuously from a polyphase circuit.

In the case of a **two-phase test,** the test on each element shall be made at unity power factor.

In the case of a **three-phase test,** a balanced three-phase load shall be obtained in the testing circuit, so that the test upon each element is made with the same conditions as those existing in service when both elements are connected to a balanced polyphase load in which the power factor is unity.

Items No. 1 *to* 4, *inclusive:* The change produced in the performance of a meter, using only one meter element as compared with that when both elements are in circuit, shall not exceed that specified below:

Item No.	Connections Meter Elements	Per Cent Rated Current	Maximum Deviation in Per Cent from Reference Performance
Reference performance..	Both elements in circuit	10	.....
1	Element A only	20	±2.0
2	Element B only	20	±2.0
Reference performance..	Both elements in circuit	100	.....
3	Element A only	140	±2.0
4	Element B only	140	±2.0

68. **Test No. 4. Effect of Variation of Power Factor—Both Elements in Circuit.** *Test conditions:* The test shall be made at calibration voltage and rated frequency. Each meter shall be tested on a balanced polyphase load.

Items No. 1 *to* 4, *inclusive:* The effect of variation of power factor upon the performance of the meter shall not exceed that specified below:

Item No.	Per Cent Rated Current	Per Cent Power Factor	Maximum Deviation in Per Cent from Reference Performance
Reference performance items 1 and 2......................	10	100	.....
1	13	75 lagging	±1.5
2	20	50 lagging	±3.0
Reference performance items 3 and 4......................	100	100	.....
3	100	75 lagging	±1.5
4	100	50 lagging	±3.0

69. **Test No. 5. Effect of Variation of Power Factor—Individual Elements.**

TWO-PHASE TESTS

Test conditions: The test shall be made at calibration voltage and rated frequency. Each meter shall be tested with the voltage circuits connected to a symmetrical polyphase voltage, but with load on only one current circuit, at the values of current and power factor specified.

Items No. 1 *to* 4, *inclusive:* The effect of variation of power factor upon the performance of the meter shall not exceed that specified below for each element:

Item No.	Per Cent Rated Current	Per Cent Power Factor	Maximum Deviation in Per Cent from Reference Performance
Reference performance	20	100	.....
1	27	75 lagging	±1.5
2	40	50 lagging	±3.0
Reference performance	150	100	.....
3	150	75 lagging	±1.5
4	150	50 lagging	±3.0

THREE-PHASE TESTS

Test conditions: The test shall be made at calibration voltage and rated frequency. Each meter shall be tested with the voltage circuits connected to a balanced polyphase circuit, but with load on only one current circuit at the values of current and power factor specified.

Items No. 1 *to* 6, *inclusive:* The effect of variation of power factor upon the performance of the meter shall not exceed that specified below. The specified power factor refers to the power-factor relation of the current and voltage applied to the element.

Item No.	Per Cent Rated Current	Per Cent Power Factor	Maximum Deviation in Per Cent from Reference Performance
	Leading Element		
Reference performance	23	86.6 leading	.....
1	20	100.0	±1.5
2	23	86.6 lagging	±3.0
Reference performance	150	86.6 leading	.....
3	150	100.0	±1.5
4	150	86.6 lagging	±3.0
	Lagging Element		
Reference performance	23	86.6 lagging	.....
5	40	50.0 lagging	±3.0
Reference performance	150	86.6 lagging	.....
6	150	50.0 lagging	±3.0

70. **Test No. 6. Effect of Variation of Voltage.** *Test conditions:* The test shall be made at rated frequency and unity power factor.

Items No. 1 to 8, inclusive: The effect of variation of voltage upon the performance of a meter carrying constant load in watts shall not exceed that specified below, provided that only meters with a voltage rating extending over a range greater than fifteen per cent (15%) of calibration voltage shall be subjected to the last four items of this test. Each meter shall be tested with a balanced polyphase load at the various values of current and voltage given below:

Item No.	Per Cent Rated Watts	Maximum Deviation in Per Cent from Reference Performance
1. Ninety per cent (90%) of calibration voltage...	10	±2.0
2. Ninety per cent (90%) of calibration voltage...	100	±1.5
Reference performance—one hundred per cent (100%) of calibration voltage—for items 1, 3, 5 and 7....	10	.....
Reference performance—one hundred per cent (100%) of calibration voltage—for items 2, 4, 6 and 8....	100	.....
3. One hundred and ten per cent (110%) of calibration voltage....	10	±2.0
4. One hundred and ten per cent (110%) of calibration voltage....	100	±1.5
5. Ninety-five per cent (95%) of minimum marked voltage....	10	±2.0
6. Ninety-five per cent (95%) of minimum marked voltage....	100	±1.5
7. One hundred and five per cent (105%) of maximum marked voltage....	10	±2.0
8. One hundred and five per cent (105%) of maximum marked voltage....	100	±1.5

71. **Test No. 7. Effect of Variation of Frequency.**—*Test conditions:* The test shall be made at calibration voltage and unity power factor. Each meter shall be tested with a balanced polyphase load.

Items No. 1 *to* 4, *inclusive:* The effect of variation of frequency upon the performance of a meter carrying constant load shall not exceed that specified below:

Item No.	Per Cent Rated Current	Per Cent Rated Frequency	Maximum Deviation in Per Cent from Reference Performance
Reference performance.........	10	100	.....
Reference performance.........	100	100	.....
1	10	95	±1.5
2	100	95	±1.5
3	10	105	±1.5
4	100	105	±1.5

72. **Test No. 8. Effect of External Magnetic Field.** *Test conditions:* The test shall be made at calibration voltage, rated frequency and unity power factor. The change produced in the performance of a meter at ten per cent (10%) of rated current by the application of an external magnetic field in the manner stated shall not exceed one per cent (1.0%). One of the meters shall be subjected to an alternating magnetic field of the same frequency as that of the testing current and produced by a straight conductor six feet long, with return leads arranged to form a rectangle six feet square. A current of 50 amperes in phase with the voltage applied to one of the voltage circuits of the meter shall be passed through this conductor. The return leads of the conductor shall be so arranged that the loop which they form does not surround or include the meter.

Place the straight six-foot conductor in each of the following positions:

Item No. 1: Behind the test board in a horizontal position and parallel to the back of the meter. The middle of the conductor shall be fifteen inches directly behind and on a level with the center of the moving element. The loop shall be in a horizontal plane perpendicular to the test board.

Item No. 2: Directly behind the center line of the meter in a vertical position. The middle of the conductor shall be fifteen inches directly behind and on a level with the center of the moving element. The loop shall be in a vertical plane perpendicular to the test board.

Item No. 3: Vertically at the same distance in front of the test board as the center of the moving element. The middle of the conductor shall be on a level with the center of the moving element and fifteen inches to the right or left. The loop shall be in a vertical plane parallel to the test board.

Item No.	Per Cent Rated Current	Position of Conductor	Amperes in Conductor	Maximum Deviation in Per Cent from Reference Performance
Reference performance	10	....	....	.....
1	10	See item 1 above	50	±1.0
2	10	See item 2 above	50	±1.0
3	10	See item 3 above	50	±1.0

Items No. 4, 5 *and* 6. Each of the above items shall be repeated with the current producing the stray-field effect in phase with the voltage applied to the voltage circuit of the other element.

73. **Test No. 9. Effect of Variation of Temperature.** *Test conditions:*

(a) The test shall be made at calibration voltage, rated frequency and unity power factor, and shall be applied to three meters, excepting that when less than five meters are submitted as specimens, the test may be applied to less than three meters.

(b) The per cent difference in the performance of the meter at the higher temperature from that at the lower temperature, divided by the difference in temperature, is the average temperature coefficient. The average temperature coefficient shall not exceed twelve-hundredths per cent (0.12%) per deg. cent. at either ten per cent (10%) or one hundred per cent (100%) of rated current.

The meter shall be placed in a space having a temperature of approximately 20 deg. cent., or room temperature, as specified in Section IV-37, and allowed to stand for not less than two hours with the voltage circuits of the meter energized. A load of ten per cent (10%) of the rated current shall then be applied, and after running for one hour, the meter shall be tested at this load. A load of one hundred per cent (100%) of rated current shall then be applied for one hour, and the meter again tested at this load. These operations shall be repeated in the same order at a temperature approximately 20 deg. cent. higher.

Item No.	Per Cent Rated Current Applied for One Hour Before Test	Ambient Temperature	Temperature Coefficient Per Cent per °C
Reference performance..	10	Room or approx. 20° C.	.....
Reference performance..	100	Room or approx. 20° C.	.....
1	10	20° C. higher than room	0.12
2	100	20° C. higher than room	0.12

74. **Test No. 10. Effect of Temporary Overloads.** *Test conditions:* The test shall be made at calibration voltage, rated frequency and unity power factor, and shall be applied to not less than three meters, excepting that when less than five meters are submitted as specimens, the test may be applied to less than three meters. The two elements shall be connected together on a single-phase circuit with their voltage circuits in parallel and their current circuits in series. The effect of temporary overloads upon the performance of the meter shall not exceed one per cent (1%) at either ten per cent (10%) of rated current (Item 1), or one hundred per cent (100%) of rated current (Item 2). A temporary load of four times the rated current shall be applied three times to each meter under test, the duration of each overload being approximately two seconds. The overload current shall be approximately in phase with the voltage applied to the voltage circuit of the meters. Each meter shall be tested with ten per cent (10%) of rated current and one hundred per cent (100%) of rated current both before and after the application of the overload.

Item No.	Per Cent Rated Current	Number of Appli-cations	Duration of Appli-cation in Seconds	Maximum Deviation in Per Cent from Reference Performance	
				10% Current	100% Current
Reference performance..	10	....	....	....	.....
Reference performance..	100	....	....	....	.....
1	400	3	2	±1.0	.....
2	400	3	2	.....	±1.0

75. **Test No. 11. Voltage Drop or Watt Loss in Current Circuits.** *Test conditions:* The voltage drop or the watt loss in the current circuits of each meter shall be measured at one hundred per cent (100%) of rated alternating current at rated frequency; or, in the discretion of the testing authority, at one hundred per cent (100%) of rated direct current.

In meters of 25 amperes rating or less, the watt loss in each current circuit shall not exceed five watts. In meters of more than 25 amperes rating, the voltage drop in each current circuit shall not exceed fifteen-hundredths (0.15) volt. In polyphase meters, the voltage drop or the watt loss applies to each current circuit separately.

PART 2. AMPERE-HOUR METERS*

An acceptable ampere-hour meter shall measure the energy taken by a load at the voltage for which the ampere-hour meter is rated within the same accuracy limits as the corresponding acceptable watthour meters in so far as the tests apply.

PART 3. REACTIVE VOLT-AMPERE-HOUR METERS†

An acceptable reactive volt-ampere-hour meter shall measure the reactive volt-ampere-hours of a load within substantially the same accuracy limits as specified for the measurement of energy by the corresponding acceptable watthour meters.

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*In the absence of adequate experience in the use of ampere-hour meters as substitutes for watthour meters, separate specifications for their acceptance cannot at present be prepared. Until such specifications are prepared, it is suggested that as a basis for their selection the requirements for watthour meters should apply to acceptance tests of ampere-hour meters, except those involving variation of voltage or power factor.

† In the absence of adequate experience with reactive volt-ampere-hour meters and their auxiliary apparatus, separate specifications for their acceptance cannot at present be prepared. Until such specifications are prepared, it is suggested that as a basis for their selection the requirements for watthour meters shall apply to acceptance tests of reactive volt-ampere-hour meters with the proper modifications.

SECTION V

SPECIFICATIONS FOR ACCEPTANCE OF TYPES OF AUXILIARY APPARATUS FOR USE WITH METERS

A. General

1. **Definition of Acceptable Auxiliary Device.** An acceptable auxiliary device for use with an electricity meter may be defined broadly as one which permits the combination of meter and auxiliary device to register with acceptable accuracy the energy supplied to the receiving circuit. Auxiliary apparatus, of a class included in the specifications herein contained, not belonging to an acceptable type, should not be used as a part of a standard meter installation.

2. **Acceptance Tests.** To be recognized as acceptable for use interchangeably with any and all types of meters, the apparatus shall be capable of conforming to the requirements herein specified, as determined by examination and tests by a duly selected testing authority.

3. **Limited Acceptance Tests.** When a given type of apparatus is intended only for use with a given type of meter, the apparatus and meter may be tested together under the specifications for acceptance of meter types (Section IV). If the combination passes the requirements there laid down, it may be accepted as a meter type, but the acceptance of the combination shall not imply that the individual elements thereof are acceptable separately or for use in other combinations.

B. Instrument Transformers—Test Regulations *

4. **Selection of Specimens for Test.** The selection of the specimens for test shall be governed by the same rules as laid down for meters in Section IV-11 and 12, with the following exception:

Because of the uniformity and permanency of instrument transformers, five specimens of a type are sufficient for the acceptance tests. It is not necessary that each rating be represented, provided that the various ratings of current transformers do not differ in rated primary ampere-turns by more than ten per cent (10%), and that the various ratings of voltage transformers have the same value of volts per turn, within ten per cent (10%).

5. **Type Designation and Identification.** Each transformer shall be designated by type and given a serial number by the manu-

*Throughout this code the terms "voltage transformer" and "potential transformer" are used interchangeably. See Standards A.I.E.E. No. 14; A.E.S.C., C22-1925.

facturer, to identify it as an individual. The serial number and type designation shall be legibly marked on the base, nameplate or frame of each transformer.

6. **Definition of Type of Current Transformers.** For the purposes of these specifications, all current transformers included in the same type shall be substantially equivalent in the following respects:

Primary ampere-turns at rated primary current.
Length, cross-section and shape of magnetic circuit.
Character of iron employed.
Arrangement of coils with respect to the magnetic circuit.
Resistance of secondary winding.

7. **Form of Application for Acceptance Tests of Current Transformers.** The applicant shall include the following information in the application to the testing authority for acceptance tests on the type of current transformers submitted:

(a) The rated value of primary current.
(b) The rated value of secondary current.
(c) Turn ratio.
(d) The nominal ratio of primary to secondary current.
(e) The range of primary-current values for which the transformers are intended.
(f) The rated nominal value of primary-circuit voltage.
(g) The rated nominal value of primary-circuit frequency.
(h) The range of circuit frequency for which the transformers are intended.
(i) The rated secondary burden in volt-amperes which will not result in exceeding heating limitations.
(j) The rated secondary burden in volt-amperes which will not result in exceeding the permissible accuracy tolerances for the frequencies specified in (h).
(k) The secondary burden (expressed in ohms and henries) and the value of secondary current for which the transformers have been compensated (i.e., for which the transformer assumes nominal ratio).
(l) Other identifying information as follows:

1. Name and address of applicant.
2. Name and address of manufacturer.
3. Manufacturer's type designation of the transformers.
4. Description of form; two-coil, two-stage, through-type, hinged.
5. Shape and dimensions.
6. Mounting; portable, switchboard, bus, bushing.

8. **Definition of Type of Voltage Transformers.** All voltage transformers, included in the same type, shall be substantially equivalent in the following respects:

Rated volts per turn of primary.
Length, cross-section and shape of magnetic circuit.
Character of iron employed.
Arrangement of coils with respect to the magnetic circuit.
Equivalent resistance, reduced to secondary terms, of the primary and secondary windings.

9. **Form of Application for Acceptance Tests of Voltage Transformers.** The applicant shall include the following information in the application to the testing authority for acceptance tests on the type of voltage transformers submitted:

(a) The rated value of primary voltage.
(b) The rated value of secondary voltage.
(c) The nominal ratio of primary to secondary voltage.
(d) The range of primary voltage for which the transformers are intended.
(e) The rated nominal value of primary-circuit frequency.
(f) The range of frequency for which the transformers are intended.
(g) The rated secondary burden in volt-amperes which will not result in exceeding heating limitations.
(h) The rated secondary burden in volt-amperes which will not result in exceeding the permissible accuracy tolerances for the frequencies specified in (f).
(i) The secondary burden (in volt-amperes, ohms and henries) for which the transformers have been compensated.
(j) Other identifying information as follows:

1. Name and address of applicant.
2. Name and address of manufacturer.
3. Manufacturer's type designation of the transformers.
4. Description of form; air-cooled, oil-cooled.
5. Shape and dimensions.
6. Mounting; portable, switchboard.

10. **Preliminary Adjustments.** Instrument transformers not being susceptible to adjustment, the "Preliminary Adjustments and Preparation for Acceptance Tests" are omitted.

C. Current Transformers—Requirements

11. **General Requirements.** The transformer shall be substantially constructed, in a workmanlike manner, of good material.

12. **Rigidity of Construction.** The mechanical construction shall be rigid, not permitting any change in the dimensions of the magnetic circuit, or displacement of the conductors.

13. **Secondary Terminal Connections.** Adequate means shall be provided for securely fastening the connections to the secondary terminals, to minimize the liability of the secondary circuit opening under load.

14. **Polarity Markings.** Primary and secondary leads of same polarity shall be marked for identification, in accordance with the methods specified in the standards of the American Institute of Electrical Engineers.

TEST NO. 1. INSULATION

15. *Item No.* 1. **Test of High-Voltage Winding to Low-Voltage Winding and Core.** The test voltage to be applied between the primary (high-voltage winding) and the secondary (low-voltage winding), with the latter connected to the core, shall be 2000 volts, plus two and one-quarter times the voltage of the circuit in which the transformer is designed to be used.

Item No. 2. **Test of Low-Voltage Winding to Core.** The test voltage to be applied between the secondary (low-voltage winding) and the core shall be 2500 volts.

These tests shall be made in accordance with the methods specified in the standards of the American Institute of Electrical Engineers.

TEST NO. 2. TEMPERATURE RISE

16. **Maximum Permissible Temperature Rise.** Each transformer shall comply with the temperature requirements specified in the standards of the American Institute of Electrical Engineers. The tests shall be made in accordance with the standards of the American Institute of Electrical Engineers, using the resistance method to determine the rise of temperature by measurements on the secondary winding.

TEST NO. 3. RATIO AND PHASE ANGLE

17. **Test Frequencies.** All ratio and phase-angle tests shall be made at 60 cycles and at the lowest value of frequency in the range throughout which the transformer is intended to be accurate. To be pronounced acceptable, the type shall pass the requirements on each frequency.

18. **Limited Current Range.** In case the applicant shall state that the transformer is intended to be used only over a certain range of current—in which case the nameplate shall so indicate—then only tests within this range shall apply to the transformer.

19. **Initial Demagnetization.** All current transformers shall be demagnetized before test by inserting a suitable value of resistance (about 10 ohms) in the secondary circuit with full rated alternating current through the primary winding, and gradually and continuously reducing either the primary current or the secondary resistance to zero. The demagnetization may also be accomplished by passing an alternating current of full rated value through one of the windings only, the other winding being open-circuited, and reducing the current gradually and continuously to zero. Where the transformer is demagnetized with the secondary open-circuited, care shall be taken to prevent accidents arising from excessive voltage across the secondary winding.

20. **Ratio and Phase Angle Under Normal Conditions.** Each transformer shall be tested under conditions No. 1 and No. 2, described below. The phase angle and the deviation of the ratio from its nominal value shall not, in an acceptable transformer, exceed the values specified.

Item No.	Per Cent Primary Current	Per Cent Ratio Error	Phase Angle in Minutes
1	10	±2.0	150
2	20	±1.5	90
3	40	±1.5	60
4	60	±1.5	45
5	100	±1.5	45

Each transformer shall be tested at the per cent of primary current specified with: (*Condition No.* 1) a secondary burden of 0.15 ohm of non-inductive resistance, and with (*Condition No.* 2) a secondary burden of non-inductive resistance sufficient to require the rated volt-ampere capacity of the transformer at one hundred per cent (100%) of rated current. The secondary burdens referred to above do not include the secondary winding of the transformer itself. Where the methods and apparatus employed in test are such that the above conditions of burden cannot be obtained, proper correction should be applied to the test results.

TEST NO. 4. EFFECT OF POLARIZATION

21. **Effect of Polarization on Ratio and Phase Angle.** A direct current of full rated value shall be passed through either the primary or secondary winding of the transformer.

Items No. 1 *to* 4, *inclusive.* The effect of polarization upon the ratio and phase angle of the transformer (measured under Condition No. 1, Section V-20) shall not exceed that specified below:

Item No.	Per Cent Primary Current	Maximum Deviation from Reference Performance	
		Ratio in Per Cent	Phase Angle in Minutes
Reference performance.	10	(Condition No. 1, Section V-20)	
Reference performance.	100	(Condition No. 1, Section V-20)	
1	10	±1.0	....
2	100	±0.5	....
3	10	.....	±60
4	100	.....	±30

D. Voltage Transformers—Requirements

22. **General Requirements.** The transformer shall be substantially constructed, in a workmanlike manner, of good material.

23. **Polarity Markings.** Primary and secondary leads of same polarity shall be marked for identification, in accordance with the methods specified in the standards of the American Institute of Electrical Engineers.

TEST NO. 1. INSULATION

24. *Item No.* 1. **Test of High-Voltage Winding to Low-Voltage Winding and Core.** The test voltage to be applied between the primary (high-voltage winding) and the secondary (low-voltage winding), with the latter connected to the core, shall be twice the rated primary voltage, plus 1000 volts. Where a transformer is rated for two or three primary voltages, the dielectric tests shall be based upon the maximum rated voltage.

Item No. 2. **Test of Low-Voltage Winding to Core.** The test voltage to be applied between the secondary (low-voltage winding) and the core shall be 2500 volts.

These tests shall be made in accordance with the method specified in the standards of the American Institute of Electrical Engineers.

TEST NO. 2. TEMPERATURE RISE

25. **Maximum Permissible Temperature Rise.** Each transformer shall comply with the temperature requirements specified

in the standards of the American Institute of Electrical Engineers. The tests shall be made in accordance with the standards of the American Institute of Electrical Engineers, using the resistance method in determining the rise of temperature by measurements on the high-voltage winding.

TEST NO. 3. RATIO AND PHASE ANGLE

26. **Ratio and Phase Angle Under Normal Conditions.** All ratio and phase-angle tests shall be made at the highest (not over 60 cycles) and lowest values of frequency in the range throughout which the transformer is intended to be accurate. The phase angle and the deviation of the ratio from its nominal value shall not, in an acceptable transformer, exceed the values specified.

Item No.	Load	Per Cent Rated Voltage	Per Cent Power Factor	Per Cent Ratio Error	Phase Angle in Minutes
1	No load.............	100	....	±1.0	....
2	No load.............	100	....	....	30
3	Rated volt-amperes....	100	100	±2.0	....
4	Rated volt-amperes....	100	100	....	60
5	Rated volt-amperes....	100	10	±2.0	....
6	Rated volt-amperes....	100	10	....	90

TEST NO. 4. EFFECT OF VARIATION IN VOLTAGE

27. **Effect of Variation in Voltage on Ratio and Phase Angle.** The ratio and phase angle shall first be determined with no load at rated voltage.

Items No. 1 *to* 4, *inclusive:* The effect of variation in voltage upon the ratio and phase angle of the transformer (measured with no load) shall not exceed that specified below:

Item No.	Per Cent of Rated Voltage	Maximum Deviation from Reference Performance	
		Ratio in Per Cent	Phase Angle in Minutes
Reference performance.	100	......	.....
1	90	±0.5	.....
2	110	±0.5	.....
3	90	......	±30
4	110	......	±30

E. Instrument Transformers—Acceptable Performance

28. **Tolerances in Ratio and Phase-Angle Requirements.** In no case shall a transformer be considered to fail in any item depending on the determination of the ratio unless the specified limit is exceeded by the amount of twenty-five-hundredths per cent (0.25%) of the rated ratio, or in the case of phase angles, unless the prescribed limit is exceeded by ten minutes. These values of testing error are assigned to cover possible errors in the observations and in the standards employed.

29. **Basis of Acceptable Performance.** A type of transformer shall be considered to pass and be acceptable under those specifications when each of the following requirements is satisfied:

(a) Current transformers shall withstand the high-voltage test specified in Section V-15, and voltage transformers shall withstand the high-voltage test specified in Section V-24.

(b) In the ratio and phase-angle tests, not over two transformers shall fail in a given item of a given clause.

(c) No individual transformer shall fail in more than three items.

(d) The total number of failures, including all the transformers and all the items of each clause, shall not exceed five.

F. Shunts

30. **Mounting of Shunts; Accessory Parts.** Shunts not intended for switchboard service should be mounted on a suitable insulating base and properly protected from tampering or mechanical injury. Each shunt should be provided with the necessary leads, lugs and lug bolts.

31. **Identification and Polarity Markings.** The shunt should be plainly and permanently marked with a serial number, the rated current and the rated millivolt drop at rated current. When the current taken by the meter exceeds one per cent (1%) of the line current rating of the shunt, this fact should be indicated. Where it is necessary to consider polarity when connecting the meter in service, the polarity should be permanently marked on the shunt, on both ends of the shunt leads and at the terminals of the meter.

32. **Maximum Permissible Temperature Rise.** The maximum temperature rise at full load should not exceed 85 deg. cent.

33. **Limited Acceptance Tests.** Other laboratory tests for acceptability shall be made on the meter and shunt as a combination (Section V-3).

SECTION VI

INSTALLATION METHODS

A. Location of Meters

1. The question of meter location should be carefully considered in the first stages of laying out the installation. It is to the interest of both the customer and the company that a location be provided such that the accuracy of the meters may be maintained, and that they may also be conveniently read and tested.

2. Contractors and architects should be informed as to the requirements for meter installations. The provisions for installing the meters must meet the approval of the company's representative, especially in regard to facilities for testing and location.

3. It is recommended that all meters installed on customers' premises should be located in the cellar or first floor, as near as possible to the point of service entrance, in a clean, dry, safe place, not subject to great variations in temperature, and on a support free from vibration. Where meters are installed out-of-doors, they should be protected from the weather.

4. Meters should be easily accessible for reading, testing and making necessary adjustments and repairs. When a number of meters are placed on the same meter board, the distance between centers should not be less than 15 inches for direct-current meters and 10 inches for alternating-current meters. Each meter loop should be so tagged or marked as to indicate the circuit metered. Meters should not be less than four feet nor more than seven feet above the floor or a suitable permanent platform.

5. An ideal location may not be obtainable in old buildings, particularly those which have been wired for some time, and under these conditions a compromise must be made by choosing the location with the fewest undesirable features.

6. Meters should not be installed in coal or wood bins, or on the partitions forming such bins, nor on any unstable partitions or supports. They should not be installed in attics, bedrooms, sitting-rooms, bathrooms, show windows, restaurant kitchens, over doors, over windows or in any location where the visit of the meter reader or tester will cause annoyance to the customer.

B. Selection of Meters

7. The meter or meters assigned to each installation must be suited to the voltage, frequency, character of the circuit and

the load and should be chosen with a view to obtaining the best adaptation to the local conditions and to the load.

8. Meters are generally most accurate when operating between twenty-five per cent (25%) and one hundred and twenty-five per cent (125%) of their current rating. The meters for a given installation should be so chosen that the average load comes well within these limits and as near to the current rating of the meter as is possible without danger of damaging the meter or lowering its accuracy. Where the maximum load is of very short duration or occurs only at rare intervals, the preference should be toward lower meter ratings. If, however, the duration of the light load is short, compared with that of the heavy load, the meter should be chosen to give the best accuracy under the latter condition.

9. The connected load is generally taken as the sum of the ratings of all the apparatus connected to the circuit. The percentage of the connected load which is in use at any one time is dependent upon the character of the installation and the business of the customer, and it is at this point that the greatest uncertainty is encountered in choosing the proper size of meter or meters. In large installations the question may be settled by a study of individual cases, but for small installations it is necessary to adopt general rules for various classes of customers.

10. In residences and apartments, meters rated at about forty per cent (40%) of the connected load, as a rule, may be used. Ordinary stores require meters rated at about sixty per cent (60%) of the connected load, but large wholesale houses, where the lights are in use only when exhibiting goods, should be treated similarly to residences. It is not, however, customary to use meters of lower rating than five amperes.

11. For single motors the meter capacity is usually equal to the current rating of the motor. When several motors are connected through the same meter, the diversity factor of the load often is such that a meter rated at much less than the combined ampere ratings of the motors may be used.

12. In large installations it may sometimes be advantageous to subdivide the load, metering the various divisions independently. Small loads of long duration should be metered separately from large loads of short duration. Two or more loads whose maximum values are equal but occur at different times may advantageously be combined on one meter. Two or more loads of unequal value may also be combined, provided that the smaller load is never used without the larger. In some cases, on account of the diversity factor of the installation, the average percentage

of full load at which the meters operate will be reduced rather than increased by subdividing the installation, in which case a single meter should be used.

13. In churches, theaters, department stores and factories, separate meters may advantageously be installed for the large number of lights used occasionally and the smaller number used for cleaning, or for exit lights.

14. Aside from the question of accuracy of metering, the subdivision of the installation has advantages. The consequences of failure or of error in a single meter are diminished, less special equipment for testing is needed, and reasons for fluctuations in the bills are more easily determined. Its disadvantages are that the investment and the labor of testing, reading and billing are, on the whole, increased, and that on account of the diversity factor of the installation, the smaller meters must have a greater aggregate rating than would be required if a single meter were used for the whole installation.

15. In very large installations, which are metered as a single circuit, it is sometimes found advantageous to connect several meters in parallel, instead of using a single meter of large capacity. To prevent disproportionate loading, care should be taken to make the resistances and reactances, in the several current paths through the meters, inversely proportional to their current ratings.

C. Wiring for Metering

[*Note—This section deals only with those aspects of wiring necessary to satisfactory metering and, therefore, no regulations as to allowable drop, balancing of three-wire circuits, grounding, etc., are included, nor are the regulations of this section intended to duplicate or conflict with the National Electrical Code.*]

16. Applications for service which are signed by the customers should state that the company has the right to inspect all circuits and apparatus at any reasonable time to insure that they are properly metered.

17. No meter should be connected so that its registration includes the registration of another meter, except for purposes of special investigation, or where required by special conditions.

18. Where several meters are grouped together, the circuits or premises to which each meter is to be connected should be plainly marked, and all circuits should be carefully traced to insure that there is no error in the wiring whereby one consumer obtains current through a meter for another customer. This

is especially important where the wiring is concealed, in which case the service and load wires should be tagged.

19. It is good practice to employ devices which, together with the continuous conduit and the sealed service cutout, enclose and seal all the wiring around the meter. Complete protection is thus provided for the service wires to the meter.

20. Proper facilities, approved by the company, should be provided in the wiring system for the connection and installation of the meter in circuit.

21. Where the connected installation includes induction coils, radio transmitting apparatus, high-potential testing transformers, and other devices which produce high voltage or high frequency, and which may injure the meter or interfere with accurate registration, the customer shall provide an approved device, capable of protecting the company's apparatus. The apparatus required will differ under different conditions, and should be designed and installed after consultation with, and with the approval of, the engineers of the company.

SECTION VII

WATTHOUR METER TEST METHODS

A. Definitions and Symbols

1. **Rotating Element.** That part of the motor element which rotates at a speed proportional to the power integrated by the meter.

2. **Register.** That part of the meter which registers the revolutions of the rotating element in terms of units of electrical energy.

3. **Dials.** The graduated circles over which the dial pointers move.

4. **Register Face.** That part of the register on which the dials are printed.

5. **Dial Pointers.** Those parts of the register which move over the dials and point to the numbers on the divisions of the dials.

6. **First Dial.** The graduated circle over which the most rapidly moving dial pointer moves.

7. **Dial Train.** All the gear wheels and pinions used to interconnect the dial pointers.

8. **Register Ratio** (R_r) The number of revolutions of the wheel meshing with the worm or pinion on the rotating element, for one revolution of the first dial pointer.

9. **Gear Ratio** (R_g). The number of revolutions of the rotating element for one revolution of the first dial pointer.

10. **Register Reading.** The numerical value indicated on the dials by the dial pointers. Neither the register constant nor the test dial, if any exist, is considered.

11. **Register Constant** (K_r). The factor used in conjunction with the register reading in order to ascertain the total amount of electrical energy, in the desired unit, that has passed through the meter.

12. **Standard Register.** One in which each of the four dials is divided into ten equal parts, the division marks being numbered from zero to nine and the gearing between the dial pointers is such that the relative movements of adjacent dial pointers are in opposite directions and in a 10 to 1 ratio. The register constant may be 1, 10 or any power of 10. Nothing appears on the register face in addition to the dials except the word "kilowatthours" and the register constant.

13. **Registration.** The numerical quantity expressed in the desired unit corresponding in value to the energy that has passed through the meter. It is equal to the product of the register reading and the register constant. The registration during a given interval of time is equal to the product of the register constant and the difference between the register readings at the beginning and the end of the interval.

14. **Rotating Standard.** A portable form of watthour meter usually provided with a plurality of current and voltage windings and with dials indicating revolutions and fractions of a revolution of the rotating element, thus enabling an accurate comparison to be made between the standard and the meter under test.

The following definitions are for purposes of test:

15. **Motor-Type Watthour Meters.** A motor-type watthour meter consists essentially of a motor element in conjunction with a generator element in which the resultant speed is proportional to the power (i.e., rate at which energy is being delivered) and a register connected thereto by suitable gearing so as to count in terms of equivalent kilowatthours the revolutions of the rotating element, hereafter for brevity designated as revolutions.

16. **Metering Equipment as a Unit.** The following discussion is worded for the test of a watthour meter used without ratio devices such as instrument transformers or shunts. For over-all tests (e.g., on the primary metering equipments), the terms watthour meter, or meter, and such standard terms as disk constant, register constant, registration, must be understood to refer to the entire metering equipment or installation as a unit.

17. **Testing Watthour Meters.** To test a meter is primarily to determine its percentage of accuracy. Testing a watthour meter consists, first, in determining whether the number of revolutions of the meter is correct for the energy passed through the meter, and second, whether the test constant, gear ratio, and register constant bear the correct relation to each other to correctly translate these revolutions, as registered by the dials, into kilowatthours. As applied to watthour meters, meter test has in general a broader meaning than the determination of the accuracy of the meter as found and includes the examination of the meter for repairs and of the surrounding conditions for influences likely to affect the meter, and the final adjustment, if necessary, to make the meter register correctly.

18. To **calibrate** a meter is to adjust it to register correctly.

19. **Revolutions** (R). A term applied to a counted number of revolutions of the rotating element.

20. **Seconds** (S). The symbol S represents the number of seconds required for the rotating element to make the counted number of revolutions, R.

21. **Meter Watts.** The term used to designate the ratio of registration in watt-seconds to the number of seconds during which the registration took place.

22. **Meter Watthours.** The actual registration in watthours for the meter-test interval of the meter being tested.

23. **True Watts.** The average rate at which electric energy is delivered through the meter during a meter test, as indicated by standard instruments.

24. **True Watthours.** The true watthours delivered through the meter during the meter-test interval.

25. **Percentage of Accuracy.** The percentage of accuracy of a meter is the ratio, expressed as a percentage, of the registration in a given time to the true kilowatthours, and is commonly referred to as the "accuracy" or "percentage accuracy" of the meter.

26. **Percentage Error.** The percentage error of a meter is the difference between its percentage of accuracy and one hundred per cent (100%). A meter whose percentage of accuracy is ninety-five per cent (95%) is said to be five per cent (5%) slow, or its error is minus five per cent (—5%). A meter whose percentage of accuracy is one hundred and five per cent (105%) is five per cent (5%) fast, or its error is plus five per cent (+5%).

27. **Constant.** A quantity used in a formula, the value of which remains the same, regardless of the other quantities used in the formula. The principal constants used in watthour-meter testing are as follows:

(a) **Watthour Constant** (K_h). The registration of one revolution of the rotating element expressed in watthours.

(b) **Watt-second Constant** (K_s). The registration of one revolution of the rotating element expressed in watt-seconds.

(c) **Register Constant** (K_r). Defined in Section VII-11.

B. Acceptable Methods of Testing

28. The principal requirements in an acceptable method of testing are, first, accuracy, and second, economy.

29. An accuracy of metering exceeding the inherent accuracy of the meter itself cannot be obtained, however accurate the method of testing employed. It is, nevertheless, essential to aim

at the highest accuracy in testing consistent with other conditions. A method, however, which though highly accurate is so expensive that tests cannot be made with sufficient frequency, is not acceptable.

30. The accuracy of any method of testing is dependent upon a number of factors which may be broadly classified as follows:

(a) Inherent accuracy of the test standards.
(b) Errors of observation.
(c) Inherent errors of the method.

31. The **inherent accuracy** of an instrument or device used as a standard for testing watthour meters is the accuracy obtainable with reasonable skill under normal conditions of use. The inherent accuracy varies with the type of instrument or device and is affected by various factors, among which are torque, length of scale, frequency variations, wave form, ambient temperature, self-heating, friction, stray fields and inaccuracy of scale markings.

32. **Observational errors** are those due to the person making the necessary observations. The errors of this class are principally due to parallax, estimation of fractions of scale divisions, improper evaluation of instrument readings with fluctuating load, and starting and stopping rotating standards or stop watches. Observational or personal errors may be reduced to a minimum by proper training and the selection of instrument scales and period of test.

33. **Errors Inherent in the Method of Test.** A method may be subject to certain inherent errors peculiar to that method alone. For example, if a specific test method require that the current taken by the voltage circuit of the test standard should pass through the current circuit of the watthour meter, then while the resultant error might be negligible in tests at full load, it would probably be serious in tests at light loads. A second method might require that the voltage circuit of a direct-current meter be interrupted at intervals. The resultant cooling of the voltage windings would cause the meter to be fast. These examples are cited to show that before its adoption every factor entering into a method of testing should be carefully considered with regard to errors inherent in the method itself.

34. In deciding upon the relative merits of various methods of testing, the first consideration, as mentioned in Section VII-28, is accuracy. One method may employ highly accurate standards, but the method may be subject to errors in comparing the standard with the meter under test. A second method may employ less accurate standards, but the errors in taking observations may be

smaller. A third method may employ auxiliary devices entirely eliminating observational errors but introducing errors inherent in the method. When the accuracy of the final result is considered the three methods may be equally accurate. In such an event, the method would be selected on the basis of local conditions, economy and facility of operation.

C. Test Procedure

35. There are two fundamental methods of testing watthour meters, the indicating-instrument method and the rotating-standard method, each having a number of acceptable modifications.

36. In the **indicating-instrument method** a given whole number of revolutions of the rotating element is timed by means of a suitable device (usually a stopwatch), the power in true watts passing through the meter being measured at the same time by means of a voltmeter and an ammeter in direct-current tests, or by a wattmeter in alternating-current tests. The ratio of the meter watthours to the true watthours represents the accuracy of the meter under test and is usually expressed in per cent.

37. **Formulas**

P = average watts by indicating instruments
= true watts
K_h = watthour constant
K_s = watt-second constant
R = number of revolutions of disk
S = time in seconds for R revolutions
A = per cent accuracy

Then,

$$\text{meter watthours} = K_h R$$

$$\text{meter watt-seconds} = K_h R \times 3600^{*} = K_s R$$

$$\text{meter watts} = \frac{K_h R \times 3600}{S} = \frac{K_s R}{S}$$

$$A = \frac{\text{meter watts} \times 100}{\text{true watts}} = \frac{K_h R \times 3600 \times 100}{PS} = \frac{K_s R \times 100}{PS}$$

*One hour is equal to 3600 seconds.

38. In many cases, because of certain factors governing the testing, such as the type or rating of the meters to be tested or local conditions, it is preferable to adopt some modified form of the fundamental test methods.

39. Typical examples of modifications of the indicating-instrument method of testing are:

(a) The loading device may be a calibrated resistor which is used to eliminate either the voltmeter or the ammeter. The units comprising the resistor should be capable of dissipating their rated watts continuously without change in resistance and be unaffected by repeated heating and cooling. The switches, which must have negligible contact resistance, and the connecting leads, are a part of the resistor and must be maintained in perfect condition. The power in watts is directly computed from the indication of the indicating instrument used and the value of the resistor. The formulas are as follows:

P = true watts
E = average volts
I = average amperes
R = resistance in ohms

$$P = \frac{E^2}{R}$$

$$= I^2R$$

(b) In testing rotating standards or other meters where fractional parts of a revolution can be determined with accuracy, the revolutions may be counted for a given whole number of seconds. In this method the meter under test is started at the beginning of the period of test and stopped at the end of the period, this being accomplished by an automatic device connected to a seconds pendulum or a synchronous motor connected to a circuit of constant frequency. The period of test is usually 36 seconds to facilitate computations.

40. In the rotating-standard method the revolutions of the rotating element of the meter under test are compared with the revolutions and fractions of a revolution of the rotating element of a rotating standard during the same interval of time, or conversely.

41. **Formulas**

r = counted revolutions of meter under test
R = counted revolutions of rotating standard
k_h = watthour constant of meter under test
K_h = watthour constant of rotating standard.

Then, meter watthours $= rk_h$

true watthours $= RK_h$

$$\text{Percentage of accuracy} = \frac{\text{meter watthours}}{\text{true watthours}} \times 100$$

$$= \frac{rk_h}{RK_h} \times 100$$

The method may be facilitated by introducing an additional symbol, values for which may be given to the tester in tabular form.

Let R_o = the number of revolutions the rotating standard should make when the tested meter is correct.

The numbers of revolutions of two correct watthour meters on a given load vary inversely as their test constants.

$$\frac{R_o}{r} = \frac{k_h}{K_h}$$

$$R_o = \frac{k_h r}{K_h}$$

Substituting R_o in the equation for percentage of accuracy

$$\text{Percentage of accuracy} = \frac{R_o}{R}\ 100$$

42. The rotating-standard method is much less susceptible to errors due to fluctuations in load than other methods, since the standard, as well as the meter under test, integrates the various values of load. On account of the fact that each individual test requires a number of revolutions of the standard, thus obtaining a result equivalent to an extremely long scale, minor errors in reading are of less importance in the use of rotating standards than in the use of indicating instruments.

43. The usual manner of comparing the revolutions of the standard and the meter, particularly for system tests, is to start the rotating standard at the beginning and stop it at the end of a given number of revolutions of the meter by means of a suitable controlling switch. Various modifications of this procedure may be used advantageously for certain classes of testing. Typical examples of such modifications are given below.

44. **Methods in which both standard and meter under test, or either, are started and stopped.**

(a) The standard and meter, or meters, under test may be started and stopped simultaneously, usually by means of a manually operated switch in the current circuit. This method is principally advantageous when a number of meters are to be tested at the same time. The period of test is generally for a number of revolutions of the standard equivalent to a whole number of revo-

lutions of the meters under test when the latter are 100 per cent accurate. The correct revolutions of the standard and the accuracy of the meters under test may be computed by the following formulas:

R $=$ correct revolutions of standard
r $=$ correct revolutions of meter under test
K_h $=$ watthour constant of standard
k_h $=$ watthour constant of meter

$$RK_h = rk_h$$

$$R = \frac{rk_h}{K_h}$$

$$\text{Percentage of accuracy} = \frac{\text{actual revolutions of meter}}{\text{correct revolutions } (r)} \times 100$$

In this method the revolutions of the standard need not necessarily be a whole number.

(b) The standard may run continuously and the meter under test be started and stopped by means of an auxiliary device connected to the standard. A whole number of revolutions of the standard is selected as the test period and such as to be equal to a whole number of revolutions of the meter under test. This method, like Method 44(a), has its principal application in testing several meters in series. The formulas are the same as for Method 44(a).

45. **Methods in which both standard and meter under test run continuously.**

(a) The standard and the meter under test may run continuously. The two are so situated in relation to each other that the relative speeds of the two rotating elements may be noted. A standard is selected having the same test constant as the meter under test, and the meter is correctly calibrated when the two rotating elements revolve in synchronism. This method is particularly applicable in the calibration of meters where it is not necessary to make "as found" accuracy tests, although the accuracy may be determined as described in Method 45(b) following.

(b) Both the standard and the meter may be allowed to run continuously and a distinct signal transmitted to the tester at each revolution of the standard. This signal may be produced through an electrical contact on the rotating element of the standard. In this method a definite number of complete revolutions of the standard is compared with the number of complete and fractional revolutions of the meter under test during the same period of time. When the meter is correct an index mark on its rotating element will occupy the same relative position at each successive signal. If D is the fraction of a revolution of the meter under test which is lost or gained in N revolutions of the standard, and the

test constants of the meters are the same, percentage of error of the meter relative to the standard is numerically $\frac{D}{N}$ 100. When constants are different, the ratio of the correct numbers of revolutions for each will be the inverse ratio of the watthour constants. This method, like Method 45(a), is especially applicable to the final calibration of the meter, since the adjustments can be gradually changed while watching the revolutions of the meter under test until the two meters run in synchronism.

46. **Ratio Devices.** Portable, self-contained rotating standards are limited in rating and therefore ratio devices or multipliers are necessary in testing meters of high ratings.

47. For **alternating-current circuits,** current and potential transformers are accurate and convenient for this purpose. Both types are supplied in portable form, and in many cases arranged with a plurality of primary windings so that they may be connected for any one of several primary ratings. In using instrument transformers in connection with rotating standards, the ratios and phase angles of the transformers must be taken into account.

48. For **direct-current circuits,** standard instrument shunts or shunts of special design may be used as the current-ratio device. Resistances are usually used as the voltage-ratio device. There are two general methods of using shunts in connection with rotating standards. In the first method the current element of the standard is connected across the terminals of the shunt in the same manner as for indicating instruments. The major precautions to be taken to avoid errors inherent to this method relate to:

(a) Changes in the resistance of the current circuit of the standard. The resistance of the current circuit, including the leads, is necessarily small as the full-load voltage drop across the shunt does not generally exceed 100 millivolts. Any change, therefore, in the resistance of this circuit may seriously affect the accuracy of registration of the standard. Changes in contact resistance between the meter terminals or the shunt and the connecting leads likewise will affect the accuracy.

(b) Thermoelectromotive Effects. Since the current circuit is composed of different metals, differences of temperature in the circuit may set up thermoelectromotive force which, unless compensated, may be of sufficient magnitude to introduce unallowable errors.

(c) The effects of stray fields should be made inconsiderable.

49. In a second method two shunts are employed, a primary shunt of large current rating and a secondary shunt of small current rating. The primary shunt is in series with the meter under

test and the secondary shunt in series with the rotating standard. In some cases the secondary shunt and the standard are in parallel with the primary shunt, both circuits being in series with the meter under test. The resistance of the two shunts is accurately determined in the laboratory and during the period of test the millivolt drop across the shunts is kept exactly equal by regulating the current through the secondary shunt. If the two shunts have one terminal in common this equality may be determined by connecting a sensitive galvanometer across the proper terminals. A differential millivoltmeter may be employed when the two shunts are independent of each other. When separate shunts are employed, the current in the secondary shunt circuit may be from an independent source.

50. Formulas

Let I = amperes in primary shunt
R = ohms of primary shunt
V = volts across terminals of primary shunt for current I
i = amperes in secondary shunt
= amperes in rotating standard
r = ohms of secondary shunt
v = volts across terminals of secondary shunt for current i
k_h = nominal watthour test constant of rotating standard
K_h = final test constant of rotating standard.

$$V = IR$$
$$v = ir$$
Since $V = v$
$$IR = ir$$

$$I = \frac{ir}{R}$$

When the current passing through the meter under test is I only:

$$\text{Final test constant } K_h = k_h \frac{I}{i}$$

$$= k_h \frac{ir}{iR}$$

$$= k_h \frac{r}{R}$$

When the current passing through the meter under test is $I + i$:

$$\text{Final test constant } K_h = k_h \frac{I + i}{i}$$

$$= k_h\left(\frac{I}{i} + 1\right)$$

$$= k_h\left(\frac{r}{R} + 1\right)$$

51. A differential dynamometer may be employed in place of the two shunts. This dynamometer is one having two opposed current windings of equal ampere-turns. One winding of a small number of turns but large current-carrying capacity is substituted for the primary shunt in the preceding method and the second winding of a relatively large number of turns and small current-carrying capacity is substituted for the secondary shunt. The movable coil is connected to any convenient source of direct current. The current through the second coil is adjusted until the pointer of the movable coil is at zero.

52. Formulas

Let I = amperes in large current coil
T = turns in large current coil
i = amperes in small current coil
t = turns in small current coil
$C = \frac{I}{i}$ for a condition of balanced torque as indicated by zero reading.
$C = \frac{t}{T}$ approximately and is determined accurately by test in the laboratory.
k_h = nominal watthour test constant of rotating standard
K_h = final watthour test constant of rotating standard.

When the current passing through the meter under test is I only:

$$\text{Final test constant } K_h = k_h \frac{I}{i}$$

$$= k_h C$$

When the current passing through the meter under test is $I + i$:

$$\text{Final test constant } K_h = k_h\left(\frac{I+i}{i}\right) = k_h\left(\frac{I}{i} + 1\right)$$

$$= k_h(C+1)$$

D. Methods of Loading

53. The following general means of loading for purposes of test are available:

- The customer's load
- A resistor
- A storage battery
- A load transformer, from the low-voltage secondary of which the testing current is taken.

54. The use of the customer's load is generally to be avoided to prevent misunderstandings and annoyance. In some cases, as in certain installations where instrument transformers are used in connection with the watthour meter, and in addition the load is constant, testing with the customer's load offers a convenient means of proving the meter connections at the same time the meter is tested. In such cases, special facilities are provided for connecting the test standards in circuit.

55. Storage batteries and load transformers furnish current for the current circuits of the meter and standard at a low voltage, the voltage circuits remaining connected to the line. An artificial meter load is thus obtained, especially adapted to the testing of meters of large rating.

E. Connections for Testing

56. The meter should preferably be shunted, so that the test may be made without interruption of the supply to the customer.

57. The load wires should be entirely disconnected from the meter to preclude the possibility of an error in the results due to a load in the customer's circuit.

58. When demand devices are used in connection with the watthour meter, the necessary precautions should be taken that the indication of the customer's maximum demand by the device shall not be influenced by the tests on the watthour meter.

59. The connections of the testing load to the load side of the meter should be made only after all other connections are completed. The voltage circuits of direct-current meters should not, however, be left disconnected from the line while making connections, on account of the error due to the change of resistance by cooling.

60. Care should be exercised not to apply to any range of the standard a load greatly in excess of its rating or scale range. The load should be off while making all changes in connections.

61. In the case of two-wire meters with both sides of the circuit passing through the meter, each current coil of the meter should be shunted. The loading device should be so connected that the test current will pass as in service, through both current circuits of the meter.

62. Three-wire meters may be tested in the meter laboratory for equality of elements, as specified in Test No. 3, Section IV-49.

63. The following methods of connection may be used in testing three-wire meters:

(a) The normal service connections may be used, the loading device being connected between the outer wires on the load side of the meter. This requires a loading device adapted to the full voltage of the system.

(b) The current coils may be connected in series and the meter tested as a two-wire meter, connecting the load on one side of the three-wire circuit.

(c) The current coils may be connected in series to an independent testing circuit, such as a storage battery or load transformer.

F. Polyphase Meters

64. Polyphase meters should be tested in the meter laboratory before installation, for equality of elements, as specified in Test No. 3, Section IV-67.

65. Polyphase meters may be tested in service by any of the following methods:

(a) The tests may be made on each element, separately, the voltage circuits of the meter being connected to a polyphase circuit in the same manner as in service, the various percentages of load then referring to the percentage of the wattage rating of the meter, provided that no test shall be made at a load exceeding one hundred per cent (100%) of the current rating of one element. The standards are used in the same manner as in single-phase tests.

(b) The tests may be made by connecting the voltage coils in parallel and the current coils in series and testing as a single-phase meter.

(c) The tests may be made by connecting the voltage coils in parallel and testing each element separately, the percentage of load then referring to the percentage of the wattage rating of the meter, provided that no test shall be made at a load exceeding one hundred per cent (100%) of the current rating of one element.

(d) The tests may be made with an approximately balanced polyphase load. When testing meters on a polyphase load, the standards should be connected as specified on page 8, Section I,

clauses 32a and 32b. In testing meters in service, it is not permissible to use methods described in clauses 32c and 32d, since errors will occur if the load is not exactly balanced.

(e) The tests may be made, in the case of a three-phase circuit, on a balanced open-delta load.

66. The mutual reaction between the eddy current generated in the rotating element of an induction-type watthour meter by the alternating field of the voltage winding and the field itself, results in a retarding effect on the rotating element, similar to, but much less in magnitude than that produced by the permanent magnets. It is, however, not negligible, but as the field is practically constant, the retarding effect is proportional to the speed of rotation of the rotating element, and may be considered as a part of the damping.

Hence, all "as found" and "as left" accuracy tests must be made with all voltage circuits energized.

67. The standards used in testing polyphase meters may be:

(a) A single-phase indicating wattmeter or a single-phase rotating standard.

(b) A polyphase indicating wattmeter or a polyphase rotating standard. When polyphase standards are used, they must be properly calibrated for polyphase conditions, with particular respect to interference between elements and balance of elements.

G. Meters with Instrument Transformers

68. A meter installed with potential and current transformers must be correctly calibrated for use with these transformers. The meter may be calibrated directly by connecting the test standards in the primaries of the transformers. In such tests, the secondary burden of the transformers should be the same as in service. Generally, the character of the installation is such as to make a primary test difficult or impossible.

69. The meter may be tested independently of the transformers, provided the transformer ratios and phase angles are determined and are taken into account in the calibration of the meter.

70. The test constant, that is the watthour constant or watt-second constant as marked on the meter, is generally that for the meter in combination with the transformers, and is called the primary test constant. For a secondary test, the test constant is the primary test constant divided by the product of the nominal ratios of transformation.

71. The ratio and the phase angle are the two transformer characteristics to be considered in a secondary test of a meter used in connection with instrument transformers.

72. The voltage or current delivered by the secondary of a transformer to the meter may be greater or less for a given primary voltage or current than the marked ratio of the potential or current transformer respectively indicates. A meter connected to a transformer, therefore, may be fast or slow unless some correction is made in the meter accuracy to compensate for the difference.

73. The phase angle of an instrument transformer causes a difference in the phase relation of the voltage or current in the secondary circuit, from the corresponding phase relation in the primary circuit. The effect of a phase angle depends on the cosine of the angle of lag or lead in the primary circuit, and the direction and magnitude of the phase angle of the instrument transformer. The phase displacement introduces a negligible error in the meter accuracy at unity power factor, but the effect increases in importance as the power factor decreases.

74. The correction factor is that factor by which the registration of a meter unadjusted for ratio or phase angle of an instrument transformer or transformers must be multiplied, to obtain the correct registration. It is also the accuracy of a meter, properly calibrated, when the meter is tested independently, so that, when used with the transformers, it will correctly integrate the energy in the primary circuit.

75. The following formulas may be employed to obtain the correction factors for use in testing meters independently of potential and current transformers:

Let

K = Ratio correction factor for combined potential and current transformers.

K_f = Final correction factor for combined potential and current transformers.

V = Ratio correction factor for voltage transformer.

V_f = Final correction factor for voltage transformer.

C = Ratio correction factor for current transformer.

C_f = Final correction factor for current transformer.

$\cos \theta$ = Power factor of primary circuit.

$\cos \theta_2$ = Apparent power factor of load as measured on the secondary of the transformer or transformers.

γ = Angle by which the reversed secondary voltage lags the primary voltage.*

β = Angle by which the reversed secondary current leads the primary current.**

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*See Note A, page 84.
**See Note B, page 84.

Ratio Correction Factor

For voltage transformers, ratio correction factor

$$V = \frac{\text{actual transformer ratio}}{\text{marked transformer ratio}}$$

For current transformers, ratio correction factor

$$C = \frac{\text{actual transformer ratio}}{\text{marked transformer ratio}}$$

For voltage and current transformers combined, ratio correction factor

$$K = VC$$

Correction for Phase Angle. When a watthour meter is tested independently to correct for the phase angle of the transformer, consideration must be given at the same time to the ratio. The correction factor for phase angle *alone* is:

For voltage transformers, $\dfrac{\cos(\theta_2+\gamma)}{\cos\theta_2}$

For current transformers, $\dfrac{\cos(\theta_2+\beta)}{\cos\theta_2}$

For voltage and current transformers, $\dfrac{\cos(\theta_2+\beta+\gamma)}{\cos\theta_2}$

The combined correction factor for ratio and phase displacement is called the "Final Correction Factor."

FINAL CORRECTION FACTOR

For voltage transformers, final correction factor

$$V_f = V\frac{\cos(\theta_2+\gamma)}{\cos\theta_2}$$

For current transformers, final correction factor

$$C_f = C\frac{\cos(\theta_2+\beta)}{\cos\theta_2}$$

For voltage and current transformers combined, final correction factor

$$K_f = K\frac{\cos(\theta_2+\beta+\gamma)}{\cos\theta_2}$$

In using these formulas care must be taken to use the proper sign with β and γ.

76. Tables I and II*, giving correction factors for phase angles, are of assistance in computing the correction-factor curves for instrument transformers.

*These tables are taken from a paper by C. T. Weller, "Revised Tables of Phase Angle Correction Factors for Use in Power Measurements," *General Electric Review,* 28 p. 202, 1925. A numerical example is worked out in the paper.

TABLE I

CORRECTION FACTORS $\left(\frac{\cos\theta}{\cos\theta_2}\right)^*$ FOR PHASE ANGLE

For Lagging Current when $(\beta + \gamma)$ is Positive
For Leading Current when $(\beta + \gamma)$ is Negative

Phase Angle $(\beta+\gamma)$	APPARENT POWER-FACTOR ($\cos\theta_2$)													
	0.10	0.15	0.20	0.25	0.30	0.40	0.50	0.60	0.70	0.80	0.90	0.95	0.99	1.00
5′	0.9855	0.9904	0.9929	0.9944	0.9954	0.9967	0.9975	0.9981	0.9985	0.9989	0.9993	0.9995	0.9998	1.0000
10′	0.9711	0.9808	0.9857	0.9887	0.9907	0.9933	0.9950	0.9961	0.9970	0.9978	0.9986	0.9990	0.9996	1.0000
15′	0.9566	0.9712	0.9786	0.9831	0.9861	0.9900	0.9924	0.9942	0.9955	0.9967	0.9979	0.9986	0.9994	1.0000
20′	0.9421	0.9616	0.9715	0.9775	0.9815	0.9867	0.9899	0.9922	0.9940	0.9956	0.9972	0.9981	0.9992	1.0000
25′	0.9276	0.9520	0.9643	0.9718	0.9768	0.9833	0.9874	0.9903	0.9926	0.9945	0.9965	0.9976	0.9989	1.0000
30′	0.9131	0.9424	0.9572	0.9662	0.9722	0.9800	0.9848	0.9883	0.9911	0.9934	0.9957	0.9971	0.9987	1.0000
40′	0.8842	0.9232	0.9429	0.9549	0.9629	0.9733	0.9798	0.9844	0.9881	0.9912	0.9943	0.9961	0.9983	0.9999
50′	0.8552	0.9040	0.9286	0.9436	0.9536	0.9666	0.9747	0.9805	0.9851	0.9890	0.9929	0.9951	0.9978	0.9999
1° 0′	0.8262	0.8848	0.9143	0.9323	0.9444	0.9599	0.9696	0.9766	0.9820	0.9868	0.9914	0.9941	0.9974	0.9998
10′	0.7972	0.8656	0.9000	0.9209	0.9350	0.9531	0.9645	0.9726	0.9790	0.9845	0.9899	0.9931	0.9969	0.9998
20′	0.7682	0.8464	0.8857	0.9096	0.9257	0.9464	0.9594	0.9687	0.9760	0.9823	0.9885	0.9921	0.9964	0.9997
30′	0.7392	0.8271	0.8714	0.8983	0.9164	0.9397	0.9543	0.9648	0.9730	0.9800	0.9870	0.9911	0.9959	0.9997
40′	0.7102	0.8079	0.8571	0.8869	0.9071	0.9329	0.9492	0.9608	0.9699	0.9778	0.9855	0.9900	0.9954	0.9996
50′	0.6812	0.7886	0.8428	0.8756	0.8978	0.9262	0.9441	0.9568	0.9668	0.9755	0.9840	0.9890	0.9949	0.9995
2° 0′	0.6521	0.7694	0.8284	0.8642	0.8884	0.9194	0.9389	0.9529	0.9638	0.9732	0.9825	0.9879	0.9944	0.9994
10′	0.6231	0.7501	0.8141	0.8529	0.8791	0.9127	0.9338	0.9489	0.9607	0.9709	0.9810	0.9869	0.9939	0.9993
20′	0.5941	0.7308	0.7997	0.8415	0.8697	0.9059	0.9287	0.9449	0.9576	0.9686	0.9795	0.9858	0.9934	0.9992
30′	0.5659	0.7115	0.7854	0.8301	0.8603	0.8991	0.9235	0.9409	0.9545	0.9663	0.9779	0.9847	0.9928	0.9990
40′	0.5360	0.6923	0.7710	0.8187	0.8510	0.8923	0.9183	0.9369	0.9515	0.9640	0.9764	0.9836	0.9923	0.9989
50′	0.5069	0.6730	0.7566	0.8073	0.8416	0.8855	0.9132	0.9329	0.9483	0.9617	0.9748	0.9825	0.9917	0.9988
3° 0′	0.4779	0.6537	0.7422	0.7959	0.8322	0.8787	0.9080	0.9288	0.9452	0.9594	0.9733	0.9814	0.9912	0.9986
10′	0.4488	0.6344	0.7279	0.7845	0.8228	0.8719	0.9028	0.9248	0.9421	0.9570	0.9717	0.9803	0.9906	0.9985
20′	0.4198	0.6151	0.7135	0.7731	0.8134	0.8651	0.8976	0.9208	0.9390	0.9547	0.9701	0.9792	0.9900	0.9983
30′	0.3907	0.5957	0.6991	0.7617	0.8040	0.8583	0.8924	0.9167	0.9359	0.9523	0.9686	0.9781	0.9894	0.9981
40′	0.3616	0.5764	0.6847	0.7503	0.7946	0.8514	0.8872	0.9127	0.9327	0.9500	0.9670	0.9769	0.9888	0.9980
50′	0.3326	0.5571	0.6702	0.7388	0.7852	0.8446	0.8820	0.9086	0.9296	0.9476	0.9654	0.9758	0.9882	0.9978
4° 0′	0.3035	0.5378	0.6558	0.7274	0.7758	0.8377	0.8767	0.9046	0.9264	0.9452	0.9638	0.9746	0.9876	0.9976
10′	0.2744	0.5185	0.6414	0.7160	0.7663	0.8309	0.8715	0.9005	0.9232	0.9429	0.9622	0.9735	0.9870	0.9974
20′	0.2453	0.4991	0.6270	0.7045	0.7569	0.8240	0.8663	0.8964	0.9201	0.9405	0.9605	0.9723	0.9864	0.9971
30′	0.2163	0.4798	0.6125	0.6930	0.7474	0.8171	0.8610	0.8923	0.9169	0.9381	0.9589	0.9711	0.9857	0.9969
40′	0.1872	0.4604	0.5981	0.6816	0.7380	0.8103	0.8558	0.8882	0.9137	0.9357	0.9573	0.9699	0.9851	0.9967
50′	0.1581	0.4411	0.5837	0.6701	0.7285	0.8034	0.8505	0.8841	0.9105	0.9333	0.9556	0.9687	0.9844	0.9964
5° 0′	0.1290	0.4217	0.5692	0.6586	0.7191	0.7965	0.8452	0.8800	0.9073	0.9308	0.9540	0.9675	0.9838	0.9962
10′	0.0999	0.4024	0.5548	0.6472	0.7096	0.7896	0.8400	0.8759	0.9041	0.9284	0.9523	0.9663	0.9831	0.9959
20′	0.0708	0.3830	0.5403	0.6357	0.7001	0.7827	0.8347	0.8717	0.9008	0.9260	0.9507	0.9651	0.9824	0.9957

* $\frac{\cos\theta}{\cos\theta_2}$ may be also written $\frac{\cos(\theta_2 + \beta + \gamma)}{\cos\theta_2}$

Interpolation for correction factors corresponding to values of $(\beta + \gamma)$ lying between those given in the table, may be made without error. Interpolation for correction factors corresponding to values of $\cos\theta_2$ lying between those given in the table may be made without exceeding an error of 0.0010 in the sections of the table lying between the heavy black lines; outside of these sections, and in all cases where the adjacent values of $\cos\theta_2$ are separated by the heavy black lines, the maximum error in interpolation will exceed 0.0010.

TABLE II

CORRECTION FACTORS $\left(\frac{\cos \theta}{\cos \theta_2}\right)^*$ FOR PHASE ANGLE

For Lagging Current when $(\beta + \gamma)$ is Negative
For Leading Current when $(\beta + \gamma)$ is Positive

Phase Angle $(\beta+\gamma)$	APPARENT POWER-FACTOR (COS θ_2)													
	0.10	0.15	0.20	0.25	0.30	0.40	0.50	0.60	0.70	0.80	0.90	0.95	0.99	1.00
5′	1.0145	1.0096	1.0071	1.0056	1.0046	1.0033	1.0025	1.0019	1.0015	1.0011	1.0007	1.0005	1.0002	1.0000
10′	1.0289	1.0192	1.0142	1.0113	1.0092	1.0067	1.0050	1.0039	1.0030	1.0022	1.0014	1.0010	1.0004	1.0000
15′	1.0434	1.0288	1.0214	1.0169	1.0139	1.0100	1.0075	1.0058	1.0044	1.0033	1.0021	1.0014	1.0006	1.0000
20′	1.0579	1.0383	1.0285	1.0225	1.0185	1.0133	1.0101	1.0077	1.0059	1.0043	1.0028	1.0019	1.0008	1.0000
25′	1.0723	1.0479	1.0356	1.0281	1.0231	1.0166	1.0126	1.0097	1.0074	1.0054	1.0035	1.0024	1.0010	1.0000
30′	1.0868	1.0575	1.0427	1.0338	1.0277	1.0200	1.0151	1.0116	1.0089	1.0065	1.0042	1.0028	1.0012	1.0000
40′	1.1157	1.0766	1.0569	1.0450	1.0369	1.0266	1.0201	1.0154	1.0118	1.0087	1.0056	1.0038	1.0016	0.9999
50′	1.1446	1.0958	1.0711	1.0562	1.0461	1.0332	1.0251	1.0193	1.0147	1.0108	1.0069	1.0047	1.0020	0.9999
1° 0′	1.1735	1.1149	1.0853	1.0674	1.0553	1.0398	1.0301	1.0231	1.0177	1.0129	1.0083	1.0056	1.0023	0.9998
10′	1.2024	1.1340	1.0995	1.0787	1.0645	1.0464	1.0351	1.0269	1.0206	1.0151	1.0097	1.0065	1.0027	0.9998
20′	1.2313	1.1531	1.1137	1.0898	1.0737	1.0530	1.0400	1.0308	1.0235	1.0172	1.0110	1.0074	1.0030	0.9997
30′	1.2601	1.1722	1.1279	1.1010	1.0829	1.0596	1.0450	1.0346	1.0264	1.0193	1.0123	1.0083	1.0034	0.9997
40′	1.2890	1.1913	1.1421	1.1122	1.0921	1.0662	1.0500	1.0384	1.0292	1.0214	1.0137	1.0091	1.0037	0.9996
50′	1.3178	1.2104	1.1562	1.1234	1.1012	1.0728	1.0549	1.0421	1.0321	1.0235	1.0150	1.0100	1.0040	0.9995
2° 0′	1.3466	1.2294	1.1704	1.1346	1.1104	1.0794	1.0598	1.0459	1.0350	1.0256	1.0163	1.0109	1.0044	0.9994
10′	1.3755	1.2485	1.1845	1.1457	1.1195	1.0859	1.0648	1.0497	1.0379	1.0276	1.0176	1.0117	1.0047	0.9993
20′	1.4043	1.2675	1.1986	1.1569	1.1286	1.0925	1.0697	1.0535	1.0407	1.0297	1.0189	1.0126	1.0050	0.9992
30′	1.4331	1.2866	1.2127	1.1680	1.1377	1.0990	1.0746	1.0572	1.0435	1.0318	1.0202	1.0134	1.0053	0.9990
40′	1.4618	1.3056	1.2268	1.1791	1.1469	1.1055	1.0795	1.0610	1.0464	1.0338	1.0215	1.0142	1.0055	0.9989
50′	1.4906	1.3246	1.2409	1.1902	1.1560	1.1120	1.0844	1.0647	1.0492	1.0359	1.0227	1.0150	1.0058	0.9988
3° 0′	1.5194	1.3436	1.2550	1.2013	1.1650	1.1185	1.0893	1.0684	1.0520	1.0379	1.0240	1.0158	1.0061	0.9986
10′	1.5481	1.3626	1.2691	1.2124	1.1741	1.1250	1.0942	1.0721	1.0548	1.0399	1.0252	1.0166	1.0063	0.9985
20′	1.5768	1.3816	1.2832	1.2235	1.1832	1.1315	1.0990	1.0758	1.0576	1.0419	1.0265	1.0174	1.0066	0.9983
30′	1.6056	1.4005	1.2972	1.2346	1.1923	1.1380	1.1039	1.0795	1.0604	1.0439	1.0277	1.0182	1.0068	0.9981
40′	1.6343	1.4195	1.3113	1.2456	1.2013	1.1445	1.1087	1.0832	1.0632	1.0459	1.0289	1.0190	1.0071	0.9980
50′	1.6630	1.4384	1.3253	1.2567	1.2103	1.1509	1.1136	1.0869	1.0660	1.0479	1.0301	1.0197	1.0073	0.9978
4° 0′	1.6916	1.4573	1.3393	1.2677	1.2194	1.1574	1.1184	1.0906	1.0687	1.0499	1.0313	1.0205	1.0075	0.9976
10′	1.7203	1.4763	1.3533	1.2788	1.2284	1.1638	1.1232	1.0942	1.0715	1.0519	1.0325	1.0212	1.0077	0.9974
20′	1.7489	1.4952	1.3673	1.2898	1.2374	1.1703	1.1280	1.0979	1.0742	1.0538	1.0337	1.0220	1.0079	0.9971
30′	1.7776	1.5141	1.3813	1.3008	1.2464	1.1767	1.1328	1.1015	1.0770	1.0558	1.0349	1.0227	1.0081	0.9969
40′	1.8062	1.5329	1.3953	1.3118	1.2554	1.1831	1.1376	1.1052	1.0797	1.0577	1.0361	1.0234	1.0083	0.9967
50′	1.8348	1.5518	1.4092	1.3228	1.2644	1.1895	1.1424	1.1088	1.0824	1.0596	1.0373	1.0241	1.0085	0.9964
5° 0′	1.8634	1.5707	1.4232	1.3337	1.2733	1.1959	1.1472	1.1124	1.0851	1.0616	1.0384	1.0248	1.0086	0.9962
10′	1.8920	1.5895	1.4371	1.3447	1.2823	1.2023	1.1519	1.1160	1.0878	1.0635	1.0396	1.0255	1.0088	0.9959
20′	1.9205	1.6083	1.4510	1.3557	1.2912	1.2086	1.1567	1.1196	1.0905	1.0654	1.0407	1.0262	1.0089	0.9957

* $\frac{\cos \theta}{\cos \theta_2}$ may be also written $\frac{\cos (\theta_2 + \beta + \gamma)}{\cos \theta_2}$

Interpolation for correction factors corresponding to values of $(\beta + \gamma)$ lying between those given in the table may be made without error. Interpolation for correction factors corresponding to values of cos θ_2 lying between those given in the table may be made without exceeding an error of 0.0010 in the sections of the table lying between the heavy black lines; outside of these sections, and in all cases where the adjacent values of cos θ_2 are separated by the heavy black lines, the maximum error in interpolation will exceed 0.0010.

77. The following typical example will serve to illustrate the procedure to be followed in calibrating a meter by means of a secondary test to compensate for the ratio errors and phase-angle errors of a potential transformer and a current transformer:

EXAMPLE

Primary rating of watthour meter 600 amperes, 2300 volts, 2-wire.

Secondary rating of watthour meter 5 amperes, 115 volts, 2-wire.

Primary watthour test constant $K_h = 720$.

Potential (voltage) transformer marked rating, 2300:115 volts, ratio 20:1.

Current transformer marked rating, 600:5 amperes, ratio 120:1.

The potential (voltage) and current transformers were tested with the following results:

POTENTIAL (VOLTAGE) TRANSFORMER

Secondary Volts	Ratio of Transformation	Phase Angle γ in Minutes
110	19.89	− 5
115	19.89	− 5
120	19.89	− 5

CURRENT TRANSFORMER

Secondary Amperes	Ratio of Transformation	Phase Angle β in Minutes
0.5	119.6	+ 25
1.25	119.3	+ 20
2.50	119.1	+ 20
5.00	118.9	+ 15

COMPUTATIONS*

The secondary watthour test constant:

$$K_h = \frac{720}{20 \times 120}$$

$$= 0.300$$

The test constant for secondary tests is 0.3 watthour.

*All results to nearest tenth of one per cent.

CORRECTION FACTORS

Correction for ratio

Ratio correction factor of voltage transformer

The average secondary voltage is 115.

$$\text{Correction factor, } V = \frac{19.89}{20.00} = 0.995$$

Ratio correction factor of current transformer

Secondary Amperes	Per Cent of Full Load	Correction Factor =C
0.50	10	$119.6 \div 120 = 0.997$
1.25	25	$119.3 \div 120 = 0.994$
2.50	50	$119.1 \div 120 = 0.993$
5.00	100	$118.9 \div 120 = 0.991$

Ratio correction factor for combined voltage and current transformers

Per Cent of Full Load	Ratio Correction Factor K=V×C
10	$0.995 \times 0.997 = 0.992$
25	$0.995 \times 0.994 = 0.989$
50	$0.995 \times 0.993 = 0.988$
100	$0.995 \times 0.991 = 0.986$

Correction for Phase Angle

The meter is to be calibrated at 100% load, 0.50 power factor lagging

Final correction factor:

$$K_f = V \times C \frac{\cos(\theta_2 + \beta + \gamma)}{\cos \theta_2}$$

For 100% load $V \times C = 0.986$

$\beta = +0°15'$

$\gamma = -0°\ 5'$ (Taken as for 115 volts)

$\beta + \gamma = +10'$

Tables I and II, pages 76 and 77, give the values of $\frac{\cos(\theta_2 + \beta + \gamma)}{\cos \theta_2}$ for various values of $\beta + \gamma$ and $\cos \theta_2$.

Since $\beta + \gamma$ is positive and the power factor is lagging, under cos Θ_2, Table I, in the column headed 0.50, and on the same line as 10′ in the left hand column headed $\beta+\gamma$, we find

$$\frac{\cos(\Theta_2+\beta+\gamma)}{\cos \Theta_2}=0.9950$$

which is the correction factor for phase angle only. The final correction factor:

$$K_f=0.986 \times 0.995 = 0.981$$

In the same manner, the final correction factors for other loads or power factors may be calculated as illustrated in the following:

50% load; 0.60 power factor lagging

$V \quad =0.995$
$C \quad =0.993$
$\beta+\gamma \quad =20'-5'= +15'$
$K_f \quad =0.995 \times 0.993 \times 0.994 = 0.982$

25% load; 0.80 power factor lagging.

$V \quad =0.995$
$C \quad =0.994$
$\beta+\gamma \quad =20'-5' = + 15'$
$K_f \quad =0.995 \times 0.994 \times 0.997 = 0.986$

78. In testing the above meter independently of the transformers, it would be calibrated with the following accuracies:

Per Cent of Full Load	*Power Factor* 1.00	*Power Factor Lagging* 0.50
10	0.992	.....
25	0.989	.....
50	0.988	.....
100	0.986	0.981

The meter is first adjusted at unity power factor, to correspond with the accuracies above shown at 10% and 100% of full load (or at some intermediate points if the condition of operation in service warrants).

The meter is adjusted for phase angle, by means of the lag adjustment. This can be accomplished for one load only. This may be 100% load or some intermediate point that may best correspond with service conditions. In the case of the above meter, if tested at 100% load, and at power factor 0.50, it should be adjusted with an accuracy 0.981. Adjustments for phase angle are usually made in the laboratory prior to installation.

79. The percentage of accuracy of a meter with instrument transformers may be determined by testing the meter indepen-

dently of the instrument transformers and using the following formulas:

Test at power factor 1.00

$$\text{Percentage of accuracy} = \frac{\text{accuracy of meter alone}}{\text{ratio correction factor (K)}}$$

Test at lower power factors

$$\text{Percentage of accuracy} = \frac{\text{accuracy of meter alone}}{\text{final correction factor } (K_f)}$$

80. Tests of ratio and phase angle of instrument transformers should be made with a secondary burden equivalent to that to be used in service.

81. The permanency of commercial instrument transformers which have not been injured by overloads, primary short-circuits, or open-circuiting the secondaries of current transformers, is such that the ratio and phase angles may be relied upon to remain unchanged for a period of at least ten years.

H. Registering Mechanism—Meter Constants

82. In the preceding clauses, descriptions have been given of methods for determining the accuracy of the meter as far as the speed of the motor element is concerned. The following concerns the relations between the register constant, watthour constant, register ratio and gear ratio. These relations are expressed by formulas given below, which are used to check the various constants and ratios, and to insure that each meter has a correct register.

83. Let

N = the numerical value of one revolution of the first dial pointer.
K_r = register constant
K_h = watthour constant
R_g = gear ratio
R_r = register ratio
R = disk revolutions

Registration of one revolution of first dial pointer,

In watthours $= K_h R_g$

In kilowatthours $= \dfrac{K_h R_g}{1000}$

For a watthour register

$$K_r N = K_h R_g$$

$$K_r = \frac{K_h R_g}{N}$$

$$R_g = \frac{K_r N}{K_h}$$

For a standard register, N = 10, therefore

$$K_r\,10=\frac{K_h R_g}{1000} \quad \text{and}$$

$$K_r=\frac{K_h R_g}{10\times 1000}$$

$$R_g=\frac{K_r\times 10\times 1000}{K_h}$$

84. The register ratio as defined in Section VII, clause 8, page 60, is the number of revolutions of the wheel meshing with the worm or pinion on the rotating element, for one revolution of the first dial pointer. In some meters, a single-pitch worm is used on the rotating element shaft, meshing with a worm wheel of 100 teeth; then

$$\text{Gear ratio, } R_g = \text{register ratio} \times 100, \text{ and}$$

$$\text{Register ratio, } R_r=\frac{\text{gear ratio}}{100}$$

In other meters a pinion is used on the rotating element shaft meshing with the gear of the register. In this case:

$$\text{Gear ratio, } R_g=\frac{\text{number of teeth in gear} \times \text{register ratio}}{\text{number of teeth in pinion}}$$

$$\text{Register ratio, } R_r=\frac{\text{number of teeth in pinion} \times \text{gear ratio}}{\text{number of teeth in gear}}$$

85. In some types of meter, the register is not constructed as a unit, so that when the register is removed, the gear wheel which meshes with the worm or pinion on the rotating element shaft (and sometimes additional gearing) remain in the meter. In all cases the definition of register ratio requires consideration of all gearing between the moving element and the first dial pointer.

86. The following methods are applicable for checking the register and gear ratios:

(a) By counting the number of teeth in the various pinions and gears and computing the ratios. This is not, in general, feasible for routine testing.

(b) Computing the correct number of revolutions and fractions of a revolution of a rapidly moving gear in the register, for one-tenth revolution of the first dial pointer. This gear is then turned manually, for this computed number of revolutions and the position of the first dial pointer noted.

(c) The register may be compared with a tested register by means of a mechanical device.

(d) The meters, after having been tested for accuracy, may be connected in series with a standard meter, and allowed to run for a period of time, as over night.

The registration of each meter at the end of the period, if the registers are correct, should be the same as that of the standard meter. This method is applicable only in the laboratory.

87. The register constant and ratios should be checked before the meter is installed in service.

I. Average Accuracy

88. The error of a watthour meter is, in general, different at light load from what it is at heavy load, and may have still other values at intermediate loads. The determination of the average error of a watthour meter, and particularly its expression as a definite single value is not a simple matter, as it involves both technical and commercial considerations. It is necessary, however, to specify a definite method for its determination, so as to provide a predetermined basis for the settlement of questions which may arise as to fast and slow meters. Two methods are at present in use—a 2-point method, which considers the average of the errors at light load and at heavy load to be the average error of a meter; and the 3-point method, which, in addition to finding the error at light and at heavy load, finds the error at normal load and gives this a weight of 3 in computing the average error.

89. The following procedure is recommended in the determination of the average percentage of accuracy by the 3-point method.

(a) All meters, whenever possible, shall be tested at three loads—one-tenth of the current rating of the meter, normal load, and at the current rating.

(b) The average of these tests, obtained by multiplying the result of the test at normal load by three, adding the results of the tests at one-tenth rating and at rating, and dividing the total by five, shall be deemed the condition of the meter.

(c) In an installation where it is impossible to obtain a load of ten per cent (10%) of the rating, or one hundred per cent (100%) of the rating of the meter, tests shall be made at the nearest obtainable loads to ten per cent (10%), and one hundred per cent (100%) of the rating of the meter and the values given in the ratios as stated above.

(d) The following classification, in percentage of installation, shall be used in determining test load:

Classification of Installation to Be Used in Testing Meters at Normal Load

A. Residence and apartment lighting...........	40%
B. Elevator service	40%
C. Factories (individual drive) churches and offices	45%
D. Factories (shaft drive) theaters, clubs, entrances, hallways and general store lighting.	60%
E. Restaurants, pumps, air compressors, ice machines and moving-picture theaters........	70%
F. Sign and window lighting and blowers.......	100%

(e) When a meter is connected to an installation consisting of two or more of the above classes of loads, the normal load must be obtained by adding the normal loads in kilowatts of the parts of the installation corresponding to the various classes.

Supplementary Notes to Section VII-75

Note A: **Phase Angle of a Potential Transformer.** The phase angle of a potential transformer is the angle between the primary voltage vector and the secondary voltage vector reversed. This angle is conveniently considered as negative when the reversed secondary voltage vector leads the primary voltage vector.

A combination of instrument transformers with a wattmeter or watthour meter is fundamentally a single measuring unit. It is convenient to consider as positive all phase angles of the transformers which tend to increase the indication of the wattmeter or watthour meter under the ordinary conditions of lagging load, and as negative all phase angles which tend to decrease it. This system results in assigning to the angles the signs as given in the above definitions. (Standards, A. I. E. E., 14-59.)

Note B: **Phase Angle of a Current Transformer.** The phase angle of a current transformer is the angle between the primary current vector and the secondary current vector reversed. This angle is conveniently considered as positive when the reversed secondary current vector leads the primary current vector. (Standards, A. I. E. E., 14-58.)

(These definitions are abstracted from the A. I. E. E. Standards, 14, March, 1925, "Instrument Transformers," approved as American Standard C 22-1925, by the American Engineering Standards Committee.)

SECTION VIII

LABORATORY AND SERVICE TESTS

A. Definitions

In addition to the various formal tests outlined in this Code, it is advisable for each company to make special tests to determine the characteristics and behavior of the meters used under its special local conditions.

It is essential to the maintenance of the accuracy of electric energy meters in service that thorough and systematic tests be made and that the meters be readjusted from time to time to eliminate the effect of conditions influencing the accuracy as enumerated in Section III, clauses 5 to 15 inclusive, pages 15-16. The character of such tests should be dictated by the requirements of the individual case. Such tests are known as Laboratory Tests and Service Tests as distinguished from Acceptance Tests of types of meters and Investigative Tests in general. These tests should be conducted according to the approved methods specified in Section VII, clauses 35 to 52, inclusive; pages 64 to 70, inclusive.

1. **Laboratory Tests.** Tests made in the laboratory of the meter department prior to installation.

2. **Service Tests.** Tests made at the place where the meters are installed. These tests are known as:

3. **Installation Tests.** Tests made within a limited period of time after installation.

4. **Periodic Tests.** Tests made at regular intervals.

5. **Request Tests.** Tests made upon request of customer.

6. **Office Tests.** Tests originating with the company and made to determine the cause of apparently abnormal registration.

7. **Repair Tests.** Tests made after meters have been repaired in service.

8. **Check Tests.** Tests made for the purpose of verifying previous tests.

9. **Referee Tests.** Tests made in the presence of representatives of regulatory bodies or a disinterested authority.

10. **Inspection Tests.** An examination of the meter and the conditions surrounding it for the purpose of discovering mechanical defects or conditions which are liable to be detrimental to its

accuracy. Such an examination may or may not include an approximate determination of the percentage of accuracy of the meter.

11. **Special Tests.** Tests covering cases other than those included in the above classification.

B. Laboratory Tests

12. **New Meters.** New meters should be unpacked with care, visually examined for damage and, if found in an acceptable condition, they should be marked according to the company's method of identification and entered in the stock records. A laboratory test should then be made to check the manufacturer's calibration and to disclose injuries due to transportation and improper alignment or adjustment of mechanical parts. The gear ratio should be determined by one of the methods given in Section VII, clause 86, page 82, and used in interchecking the register and disk constants. Where not already so marked, the watthour or watt-second constant should be marked on the meter.

13. **Accuracy Requirements.** Unless the meter percentage registration is found to be correct within the limit of one per cent (1%) the meter should be adjusted as closely as practicable to the conditions of zero error at both light and heavy loads, as follows:

Direct-Current Meters

Light Load—Ten per cent (10%) of current rating.

Heavy Load—Sixty to one hundred per cent (60% to 100%) of current rating.

Alternating-Current Meters—On Non-Inductive Load

Light Load—Five per cent or ten per cent (5% or 10%) of current rating.

Heavy Load—Sixty to one hundred per cent (60% to 100%) of current rating.

14. **Power-Factor Adjustment.** Watthour meters that are to be used on circuits of low power factor (lagging current) shall be tested as in 13 above, and also adjusted to register correctly to within two per cent (2%) plus or minus at a power factor of approximately fifty per cent (50%) and at approximately one hundred per cent (100%) of rated current.

With the meters so adjusted the remaining range of adjustment should have sufficient range in either direction to permit of adjustment under service conditions.

15. **Meters Returned from Service.** Meters returned from service should be treated substantially the same as new meters.

In the case of meters returned from service it is desirable that register readings and readings of accuracy be taken and recorded before any changes are made in the meter.

Each meter, prior to re-installation, should be thoroughly overhauled and put into first-class operating condition.

C. Test Procedure on Customer's Premises

Tests of meters on the customer's premises are made with the following objects in view:

16. **Determination of Accuracy Under Service Conditions.**

Readjusting and recalibrating.

Verifying the "as left" accuracy.

Attention is also given to such conditions as are likely to affect the accuracy of the meter or its proper registration or to render it inoperative at any time between the given test and the next periodic test.

It is advisable in all cases to issue definite rules which are to be observed in making tests on the customer's premises. While modification may be necessary to satisfy local conditions, the essential principles specified in the following procedure should be adhered to.

17. **Verification of Number.** The tester or inspector should, on reaching the meter, verify its number to insure that it is the one on which the test or investigation has been ordered.

18. **General Inspection.** An inspection should be made of the general conditions around the meter. Dirt, cobwebs and foreign material should be removed where the location is such that they are likely to fall into the meter. Conditions of temperature, overload, stray fields, or vibrations that are likely to affect the accuracy of the meter should be disturbed as little as possible prior to obtaining the "as found" tests, in order that the tests may represent the accuracy of the meter in service.

The conditions of the seals on the meter and meter cabinet should be examined and the wiring leading to the meter should be inspected to insure against improper or fraudulent connections.

Before opening the meter the reading of the register should be taken, recorded and checked.

If meter cover is removed it should be done carefully, the meter shunted when necessary and the standards connected in circuit.

19. **Initial and Test Adjustments.** No watthour meter that has an incorrect register constant, test constant, gear ratio or dial train or that registers upon no load (creeps) shall be placed in service or be allowed to remain in service without adjustment and correction.

20. **Accuracy Requirements.** No watthour meter that has an error in registration of more than plus two per cent (+ 2%), or minus four per cent (— 4%) at light load, or plus or minus two per cent (± 2%) at heavy load, shall be placed in service or allowed to remain in service without adjustment. Whenever on installation, periodic or any other tests a meter is found to exceed any one of these limits it must be adjusted.

Meters must be adjusted as closely as practicable within the tolerances specified to the condition of zero error.

21. **Creep.** A meter in service creeps when, with all load wires disconnected, the moving element makes one complete rotation in five minutes or less.

Continuous or intermittent creep which cannot be eliminated by the use of adjustments may be prevented by the use of a small piece of iron known as a "clip" fastened to the disk and so adjusted that it will be attracted by the brake magnets with just sufficient force to prevent rotation at no load. After installing the clip, final readings should be taken of starting current and accuracy at light load, and the meter adjusted if necessary.

A determination of the load required to start the meter may advantageously be made at this time.

22. **Loading.** Test for accuracy as found should be taken at the following loads:

Light Load. Equal to ten per cent (10%) of the meter current rating, in direct-current meters; five per cent (5%) or ten per cent (10%) of the meter current rating in alternating-current meters.

Heavy Load. Equal to sixty to one hundred per cent (60% to 100%) of the meter current rating.

Normal Load. When required equal to fifty to sixty per cent (50% to 60%) of the meter current rating except on Request or Referee Tests when the load determination shall be made in accordance with the rules given in Section VII, clauses 88 and 89, page 83.

23. **Maintenance.** The tester should see that the meter is properly installed, is level, securely supported and properly connected.

Conditions such as vibration, heat, moisture, chemical fumes, dust and also the causes of any abnormal condition found within the meter should be investigated and eliminated or reported for correction.

[*Caution*—In meters on grounded systems, a test should be made to determine that the current coil of the meter is in the ungrounded side of the circuit.]

24. **Recalibration.** The meter should be recalibrated with the same loads given for the "as found" tests. Final tests should be taken at each load. The meter should be reconnected, then the

cover placed and the meter sealed. The final reading of the register in all cases should then be carefully checked and recorded. Before leaving, the tester should determine that the customer's circuits are properly connected and that the meter registers.

All entries in the test record must be made at the time the corresponding work is done.

D. Installation Tests

25. **Accuracy Requirements.** All watthour meters shall be tested and adjusted to register accurately to within the limits specified in Section VIII, clause 13, page 86, before installation or adjusted accurately to within the limits specified in Section VIII, clause 20, page 88, after installation, provided that all direct-current meters shall be tested and adjusted in their place of service within sixty days after installation.

In some cases an installation inspection is made shortly after installation with a view to determining that the meter is in good operating condition, properly connected and that the location is such as to insure proper metering conditions. Where such an inspection is made, the period between the installation of the meter and the installation test may be longer than otherwise.

E. Periodic Tests

26. All meters installed on customer's premises should be tested periodically to insure continued reliability and commercial accuracy of the entire meter system. A suggested schedule for periodic tests follows.

SCHEDULE FOR PERIODIC TESTING OF WATTHOUR METERS NOT EXCEEDING 750 VOLTS

	Interval Between Tests
Direct-current Meters	
Exceeding 500 amperes	6 months
500 to 50 amperes, inclusive	18 months
25 amperes and less	42 months
Alternating-current Meters—single-phase	
Exceeding 25 amperes	24 months
25 amperes and less	60 months
Alternating-current Meters—polyphase	
Exceeding 150 amperes	12 months
150 amperes and less	24 months
Meters on circuits exceeding 600 volts	6 months

The accuracy of meters in service depends on many factors, and primarily those of design and maintenance in service.

Different locations and operation under varying conditions of use will require consideration in fixing the intervals between tests.

Meters operating at a heavy load during a considerable portion of the time, with a large registration between tests, should be tested more often than suggested in the schedule.

F. Request Tests

27. Meters should be tested on request of the customer, whenever after the elimination of other causes of dissatisfaction it appears possible that the meter may be at fault or when in the judgment of the company a test is desirable.

The basis of a request test originates with the customer as a complaint due to his interpretation of conditions surrounding the measurement of his consumption of energy as expressed to him by his bill.

G. Office Tests

28. Office tests are generally made as a result of abnormal fluctuations in the meter registration between meter reading periods other than normal fluctuations due to seasonal changes.

H. Repair Tests

29. Repairs of a nature not requiring the replacement of the meter should be followed by a repair test so as to place the meter in an accurate condition. The character of such a test is similar to the installation test and should be made as soon as possible after the repairs.

I. Check Tests

30. Check tests are an assurance that periodic tests are being made correctly and are an aid in determining the relative efficiency of employees engaged in testing. Such tests should be made within 24 hours, and should be a check on the reported "as left" accuracy and include a general examination of the meter.

J. Referee Tests

31. Referee tests are made in the presence of a representative of the customer or a representative of a regulatory body. Such a representative may connect into circuit an independent set of standards with the company's standards and the tests may be made simultaneously. A comparison of the two sets of standards should be made before the test of the meter, and if a discrepancy greater than five-tenths of one per cent (0.5%) is found at any load to be used, the location of error should be determined by

comparing the standards with primary standards before proceeding with the test. No company seal should be broken by other than an accredited representative of the company. Seals placed on meters by regulatory bodies should be broken only by their representative or with their permission by the company's representative.

The loads to be used in testing should be chosen with a view of obtaining the best measure of the accuracy with which the meter registers the energy. When the actual loads cannot be determined the method of testing at two or three loads and determining the average accuracy, as specified in Section VII, clauses 88 and 89, page 83, may be used.

K. Inspection Tests

32. Cases occur in practice where it is advantageous to obtain an approximate idea of the condition of the meter without recourse to a complete test against standards.

The method of test generally applied is to load the meter with the customer's load, estimating the wattage, or to use a calibrated-resistor load whose watt consumption is known for a number of normal voltage values, obtaining time of disc rotation with a stop watch or other reliable timing device.

SECTION IX

DEMAND METERS

Definitions

1. **Load Factor.** The load factor of a machine, plant or system is the ratio of the average power to the maximum power during a certain period of time. The average power is taken over a certain period of time, such as a day, a month, or a year, and the maximum is taken as the average over a short interval of the maximum load within that period.

In each case, the interval of maximum load and the period over which the average is taken should be definitely specified, such as a "half-hour monthly" load factor. The proper interval and period are usually dependent upon local conditions and upon the purpose for which the load factor is to be used.

2. **Demand.** The demand for an installation or system is the load which is drawn from the source of supply at the receiving terminals, averaged over a suitable and specified interval of time. Demand is expressed in kilowatts, kilovolt-amperes, amperes, or other suitable units.

3. **Maximum Demand.** The maximum demand of an installation or system is the greatest of all the demands which have occurred during the period. It is determined by measurement, according to specifications, over a prescribed time interval. In accordance with specifications, a demand may be measured by an instrument with a time lag, or an instrument integrating the load over the prescribed time interval; or the load may be determined from a sufficient number of readings of an indicating instrument, taken over the time interval.

4. **Demand Interval.** The length of the interval of time over which the demand is measured. For example, in a 15-minute demand, the demand interval is 15 minutes.

5. **Demand Factor.** The ratio of the maximum demand of any system or part of a system to the total connected load of the system or of that part of the system under consideration.

6. **Diversity Factor.** The ratio of the sum of the maximum power demands of the subdivisions of any system, or parts of a system, to the maximum demand of the whole system, or of the part of the system under consideration, measured at the point of supply.

7. **Averaged Maximum Demand.** The highest average or arithmetical mean of several similar demands. It may be com-

puted from several demands on a definite number of days, either consecutive or within certain limits of time, such as a month or a year.

8. **Simultaneous or Coincident Maximum Demand.** The greatest sum of the similar demands of a number of services occurring at the same time. It may be obtained by the summation of measurements at each service or by a single measurement at the source of supply of the group.

9. **Daily, Monthly or Annual Maximum Demand.** The maximum demand which has occurred within the specified period of time.

10. **On-Peak Maximum Demand.** The maximum demand occurring within certain designated hours, called the peak period.

11. **Off-Peak Maximum Demand.** The maximum demand occurring outside certain designated hours, called the peak period.

12. A **Demand Meter** is a device which indicates or records the demand or maximum demand.

13. An **Integrated-Demand Meter** is one which indicates or records the maximum demand obtained through integration.

14. A **Lagged-Demand Meter** is one in which the indication of the maximum demand is subject to a characteristic time lag.

Classification of Demand Meters

Class I. Curve-Drawing Instruments

15. Curve-drawing instruments giving the load-time curve of the installation or system, may be employed as demand meters. The demand interval may be of any specified length, and the demand periods may be taken as beginning at specified times of the day, or may be timed so as to include the maximum average load occurring in any period of the chosen duration.

Class II. Integrated-Demand Meters

16. An integrated-demand meter consists of a device in a combination with an integrating meter whereby the energy consumption as measured by the meter is registered from time to time in such a way that the maximum demand may be determined from the record. Two variants are recognized:

(a) Those showing the energy consumption in definite and consecutive demand intervals occurring at arbitrarily chosen times, such as 2:30 to 3, to 3:30, etc. The maximum demand corresponds to the greatest energy consumption in an interval. These instruments may be either recording or indicating. If recording on a tape or chart, the demand for any interval can be ascertained and

also the time of day at which it occurred. If indicating by means of a hand and dial, only the maximum demand is ascertainable at any subsequent time.

(b) Those recording on a tape or chart the number of equal and relatively small amounts or blocks of energy with respect to a separate and continuous record of time. The maximum demand is obtained by counting the number of such recorded points occurring within the demand interval, the time of the beginning of the interval being so chosen that the interval will include the maximum number of points. From the record, the demand for any interval can be obtained and the time of day at which it occurred. These instruments differ from those of Class II (a) in that the time of the beginning of the interval is not arbitrarily fixed.

Class III. Lagged-Demand Meters

17. These are instruments so constructed as to require a certain time interval for the indication to reach the point corresponding to the value of the load. Two variants are recognized:

(a) Those in which the speed of the indicator in moving up its scale under constant load, is constant, or at any load, is proportional to the load.

(b) Those in which the speed diminishes with the time of the deflection. (The demand interval of Class III (b) meters is ordinarily considered to be the time required for the instrument to indicate ninety per cent (90%) of the full value of a steady load which is thrown suddenly on it.)

The Concordance of Demand Meters

18. On a continuous steady load of sufficient duration, accurate demand instruments of all classes will give the same value for the maximum demand. On varying loads the values given by accurate instruments of different classes may differ because of the different underlying principles of the instruments themselves. For example: The record of an instrument of Class II (a) may differ from that of an instrument of Class II (b) if the period of maximum load occurs during two demand intervals of the (a) instrument without falling fully into either one, whereas the record of the (b) instrument may be taken so as to cover the entire period of maximum load. Furthermore, the record of a time-lagged instrument, Class III, will vary according to the character and sequence of the variations, and the behavior of a Class III (a) instrument on a varying load is different from that of a Class III (b) instrument on the same load. In commercial practice, therefore, the term "Maximum Demand" is interpreted as having the following significance;

Practical Interpretation of Maximum Demand

19. In commercial practice the maximum demand of an installation or a system is given by the record or indication of a demand meter of acceptable type which is correctly installed, properly adjusted, and none of the errors of which exceeds the limits of commercial tolerance.

Selective Meters

20. These are devices which differentiate the supply of energy with reference to a fixed value of demand or period of time as follows:

(A) EXCESS METERS

These are meters which record either exclusively or separately that portion of the energy consumption taken in addition to a predetermined load.

(B) TWO-RATE METERS

These are meters which register at different rates or on different dials at different hours of the day.

Current Limiters

21. Current limiters are devices which operate to prevent the demand of an installation from exceeding a predetermined value. Their operation may either open the supply circuit entirely or may simply reduce the voltage on the installation supply. In their operation they may be self-restoring or may require the service to be restored to its normal condition by some special means.

SPECIFICATIONS FOR ACCEPTANCE OF TYPES OF DEMAND METERS

A. General

22. **Rules Governing Acceptance Tests.** The general provisions and rules contained in Section IV, clauses 1-46, inclusive, shall, in so far as they are directly applicable, govern the acceptance of types of demand meters.

23. **Individual Treatment of Classes.** Inasmuch as there are various classes of demand meters which differ widely in their principle of operation and their method of recording the result, no general set of acceptability rules can be laid down for all classes, but rather each class shall be treated by itself.

24. **Reliability in Design and Construction.** The purely mechanical features of many classes of demand meters are of such importance that particular care shall be given to ascertain that they are of such a design and construction that they can safely

be depended upon to give continuous and reliable service. No type is acceptable, the design or construction of which involves features which make it inherently liable to error, or which requires such a delicate adjustment that it is liable in service to introduce an error or failure into the result. The design and construction shall be such that any outstanding tendency toward error is in the direction of under-registration.

25. **Alternating-Current Tests.** In the following specifications of test, conditions with respect to frequency and power factor apply only to alternating-current meters.

B. Tests for Acceptability

CLASS I. CURVE-DRAWING INSTRUMENTS

26. **General Conditions.** The instruments shall be mounted on a support free from vibration, and shall not be jarred or tapped during the tests.

The tests shall be made with the pen or stylus in operating condition and resting with normal pressure against the chart. The chart shall be moving at its normal speed, and all results (indications) shall be taken directly from it, no allowance being made for inaccuracies in travel or in the chart itself. Normal speed, when not otherwise specified, shall be the speed corresponding to that indicated on the printed chart or paper.

[Note—In the following tests polyphase meters shall be tested on a single-phase circuit, with the current windings in series and the voltage windings in parallel.]

27. **Test No. 1. Accuracy.** The indication of an acceptable meter after having normal voltage and twenty-five per cent (25%) rated current applied for at least one hour shall not differ from the true value at twenty-five, fifty and one hundred per cent (25%, 50%, 100%) of full-scale reading by an amount greater than two per cent (2%) of full-scale indication. The test shall be made first ascending the scale from twenty-five per cent (25%) to one hundred per cent (100%) and next descending the scale from one hundred per cent (100%) to twenty-five per cent (25%) of full-scale indication. The corresponding readings shall not be averaged, but the maximum error shall in each case be the only one considered.

The tests shall be made at calibration voltage, rated frequency and at unity power factor.

28. **Test No. 2. Equality of Elements, Three-wire and Polyphase Meters.** The current required to give an indication of one-half (½) full-scale value, when passed through either current winding alone, shall not differ by more than two per cent (2%) from twice the current required to give the same indication with the current windings in series.

29. **Test No. 3. Effect of Variation in Voltage.** The indications of an acceptable meter, when subjected to a voltage differing from the calibration voltage by plus or minus ten per cent (10%) of the calibration voltage, shall not vary from the indications at corresponding loads and calibration voltage by more than one and one-half per cent (1.5%) of full-scale indication. Tests shall be made at approximately fifty and one hundred per cent (50% and 100%) of full-scale indication, at rated frequency and unity power factor.

30. **Test No. 4. Effect of Variation in Power Factor, Single-Phase and Polyphase Meters.** The indications of an acceptable meter under the test conditions shall not differ from the indications at corresponding loads and unity power factor by an amount greater than two per cent (2%) of the full-scale deflection. The tests shall be made at calibration voltage and at rated frequency. Each meter shall be tested at the various values of current and lagging power factor given below:

Per Cent of Rated Current	*Power Factor Per Cent*
66	75
100	50
133	75

31. **Test No. 5. Effect of Variation in Frequency, Single-Phase and Polyphase Meters.** The indications of an acceptable meter tested at ninety-five per cent (95%) and one hundred and five per cent (105%) of rated frequency shall not differ from the corresponding indications at rated frequency and corresponding load by an amount greater than one and one-half per cent (1.5%) of full-scale indication. Tests shall be made at approximately fifty per cent and one hundred per cent (50% and 100%) of full-scale deflection.

32. **Test No. 6. Effect of Variation in Temperature.** This test shall be made as prescribed in Section IV, clause 51, except that the test shall be made at fifty per cent (50%) and one hundred per cent (100%) of rated current. The temperature coefficient of an acceptable meter, as so determined, shall not exceed two-tenths of one per cent (0.2%) per deg. cent.

33. **Test No. 7. Damping.** The tests shall be made at calibration voltage, rated frequency and at unity power factor. In an acceptable meter, a sudden increase in the load from fifty per cent (50%) of rated current to seventy-five per cent (75%) of rated current shall not cause the pen to over-travel by more than

ten per cent (10%) of full-scale indication, and the pen shall come to within three per cent (3%) of its final indication in a time interval not greater than fifteen seconds.

34. **Test No. 8. Sensitivity.** With a steady current supply at the calibration voltage, rated frequency and at unity power factor, the sensitivity shall be such that the pen responds immediately to a change of current equal to two per cent (2%) of the current corresponding to full-scale indication. The test shall be made at approximately three-quarters (¾) of full-scale indication.

35. **Test No. 9. Timing.** The chart shall be set to indicate true time, and two records of twenty-four hours each shall be taken under operating conditions, one at rated load and one at one-quarter rated load. The time indicated on the chart shall not differ from true time by more than plus or minus one-quarter of one per cent (± 0.25%) of the elapsed time. The chart shall be reset to indicate correctly at the beginning of the second twenty-four hour test.

36. **Test No. 10. Legibility of Record.** The travel of the pen from the no-current position to the full-scale position shall not be less than two and one-half inches. The character of the scale and of the line drawn shall be such that at any point on the scale from one-quarter scale to full-scale, the record may be read to within one per cent (1%) of the full-scale indication.

CLASS II. INTEGRATED-DEMAND METERS

37. **Test No. 1. Acceptability of Integrating Meters.** The integrating meter which constitutes the measuring portion of integrated-demand meters shall be subjected to the tests for acceptance for meters of its class in Section IV. All auxiliary devices necessary for the measurement of demand shall be in train and in full operation during these tests. The limits of allowable variations for an acceptable meter shall be the same as fixed in Section IV for corresponding meters independent of registering or recording devices.

38. **Test No. 2. Steps per Demand Interval.** The number of steps or their equivalent per demand interval at the rated load of the integrating meter shall be sufficiently great so that in no case shall the error introduced thereby exceed two per cent (2%) of full load.

39. **Test No. 3. Legibility of Record, Indicating and Graphic Recording Devices.** The indication or record shall be such that at any point between one-quarter full-scale and full-scale, it can be read to within one per cent (1%) of the full-scale value.

40. **Test No. 4. Equality of Energy Intervals.** The integrating meter shall be operated on a constant load of approxi-

mately one hundred per cent (100%) of its rated capacity during the time necessary for five complete revolutions of the contact wheel which sends energy impulses to the recording or registering device. The times shall be recorded at which each such energy impulse is transmitted, and by subtraction the time intervals between the energy impulses shall be found. In an acceptable device, no such energy interval shall differ from the mean of all the energy intervals by more than one per cent (1%) of one complete revolution.

41. **Test No. 5. Accuracy of Demand Intervals.** The duration of the demand interval shall be determined by a measurement of at least three successive intervals and of not less than the number of intervals in an entire cycle of the timing mechanism. In an acceptable device the lengths of these intervals shall not differ from the nominal length by more than two per cent (2%).

42. **Test No. 6. Accuracy of Contact Mechanism.** The integrated-demand meter, consisting of an integrating meter with contact mechanism and of the corresponding registering or recording mechanism, shall be operated on a load approximately equal to the full load of the integrating meter during a period of time such that not less than five hundred (500) energy impulses are transmitted. A record of these impulses shall be taken on a suitable graphic instrument (e.g., an adapted laboratory chronograph), an inspection of the chart of which will show whether the contact mechanism has failed either by sending out double impulses or by omitting any impulse. In an acceptable type of contact mechanism, no such failure shall occur.

43. **Test No. 7. Accuracy of Registering or Recording Mechanism.** Using the data of Test No. 6, the total number of energy impulses shown by the registering or recording mechanism shall be compared with the total number as given on the chart of the graphic instrument. In an acceptable type of registering or recording mechanism, these numbers shall be equal. In the case of records or indicators which reset, it is evident that the impulses lost due to the reset operation are not to be considered.

[Note—In tests No. 6 and 7 the graphic instrument used shall have such electrical constants and shall be connected in the circuit in such a way that it will not interfere with the reliability of operation of either the contact mechanism or the registering or recording mechanism.]

44. **Test No. 8. Clock.** Two twenty-four hour tests shall be made, one near the beginning and the other near the end of the winding period. In an acceptable meter the gain or loss of the clock in either test shall not exceed two minutes in twenty-four hours.

45. **Test No. 9. Timing Motors.** In meters using an electric motor instead of a clock, the timing motors shall be tested as follows:

(a) *Average Rate of Timing Motor.* At calibration voltage and at rated frequency, the average rate of the motor during a demand interval shall be such as to correspond to a gain or loss of time not to exceed two per cent (2%).

(b) *Effect of Voltage Variation on Timing Motor.* A variation of five per cent (5%) above or below the rated voltage of the timing motor shall not affect the speed of the motor by more than one per cent (1%).

(c) *Effect of Frequency Variation on Timing Motor.* A variation of three per cent (3%) above or below the rated frequency of the current applied to the timing motor shall not affect the speed of the motor by more than six per cent (6%).

(d) *Effect of Temperature Variation on Timing Motor.* A rise in temperature of 10 deg. cent. above an initial temperature of 20 deg. cent. shall not change the speed of the motor by more than two per cent (2%).

CLASS III. LAGGED-DEMAND METERS

[Note—Polyphase meters shall be tested on a single-phase circuit, with their current windings in series and their voltage windings in parallel.]

46. **Test No. 1. Accuracy of Indication.**

(a) *Meters in which the speed of the indicator is proportional to the load.* Each meter shall be tested on a load corresponding to twenty-five, fifty and one hundred per cent (25%, 50% and 100%) of full-scale indication, at calibration voltage, rated frequency and at unity power factor as follows:

With the indicator at the no-load position, a load of the prescribed amount shall be suddenly thrown on. The indication shall be noted when one-half (½) of the rated demand interval has elapsed, and again at the end of the demand interval. The indication at the end of the half-interval period shall not differ from that corresponding to one-half (½) of the applied load by more than plus or minus three per cent (3%) of the full-scale indication. The indication at the end of the time interval shall not differ from the true value corresponding to the applied load by more than plus or minus three per cent (3%) of the full-scale indication.

(b) *Meters in which the speed of the indicator decreases with the deflection.* Each meter shall be tested on loads corresponding to sixty per cent (60%) and one hundred per cent (100%) of full-scale indication at calibration voltage, rated frequency and at unity power factor, as follows:

With the indicator at the no-load position, a load of the prescribed amount shall be suddenly thrown on. The time required for the indication to reach ninety per cent (90%) of full indication shall not be more than 2 per cent (2%) below the rated de-

mand interval of the instrument. In both of the tests prescribed the loads shall be kept on the instrument until the ultimate deflection has been reached. The indication at ultimate deflection shall not differ from that corresponding to the actual load by an amount greater than five per cent (5%) of the full-scale indication.

47. **Test No. 2. Equality of Elements, Three-wire and Polyphase Meters.** The current required to give an indication of one-half (½) full-scale value when passed through either current winding alone shall not differ by more than three per cent (3%) from twice the current required to give the same indication with the current windings in series.

48. **Test No. 3. Effect of Variation in Voltage.** The test shall be the same as Test No. 3, for Class I demand meters, and the limits of allowable variation shall be the same.

49. **Test No. 4. Effect of Variation in Power Factor, Single-Phase and Polyphase Meters.** The indications of an acceptable meter under the test conditions shall not differ from the indications at corresponding loads and unity power factor by an amount greater than three per cent (3%) of the full-scale deflection. The tests shall be made at calibration voltage and at rated frequency. Each meter shall be tested at the various values of current and lagging power factor given below:

Per Cent of Rated Current	*Power Factor Per Cent*
66	75
100	50
133	75

50. **Test No. 5. Effect of Variation in Frequency, Single-Phase and Polyphase Meters.** The test shall be the same as Test No. 5, for Class I demand meters, and the limits of allowable variation shall be the same.

51. **Test No. 6. Effect of Variation in Temperature.** The test shall be the same as Test No. 6, for Class I demand meters, and the limits of allowable variation shall be the same.

CURRENT LIMITERS

52. **Test No. 1. Accuracy.** Current limiters which are adjustable to act over a range of loads shall be tested at twenty-five, fifty and one hundred per cent, (25%, 50% and 100%) of their rated capacity as follows:

The current shall be gradually and continuously increased until the limiter acts. This action shall in each case be caused by a current not less than one hundred per cent (100%) and not greater than one hundred and twenty per cent (120%) of that for which the limiter is set or calibrated. The test shall be made five times. In the case of limiters which are not adjustable without change or alteration, but which are rated for one load only, the corresponding tests shall be made only at this load.

Rules Governing the Acceptance and Rejection of Demand Meters

53. **Tolerances in Accuracy Requirements.** In no case shall a meter be considered to fail in any test involving a determination of the accuracy of the meter unless the limit of tolerance is exceeded by the amount of one-quarter per cent (0.25%) of the standard or reference quantity, this being a value of testing error assigned to cover possible errors in the standards employed and in the observations.

54. **Additional Meters for Replacements.** Meters which develop evident physical defects during the tests may be replaced from the meters held in reserve by other meters of the same size and type. If, however, more than three replacements are necessary, the type shall be rejected.

55. **Basis of Acceptable Performance.** A type of meter shall be considered to pass and be accepted under these specifications when each of the following requirements is satisfied:

(a) In the tests made on ten meters, failure of more than three meters in any one test shall cause rejection of the type.

(b) In the tests made on ten meters, a total of more than five per cent (5%) of failures of individual meters in individual tests shall cause rejection of the type. This is in accordance with the following table:

Number of meters = 10.

Number of Tests	Number of Individual Tests	Permissible Individual Failures
1	10	0
2	20	1
3	30	1
4	40	2
5	50	2
6	60	3
7	70	3
8	80	4
9	90	4
10	100	5

(c) In tests made on less than three meters, a failure of any meter in any test shall cause a rejection of the type. At the request, however, of any interested party, or when in the judgment of the testing authority, the results on fewer than ten meters are unreliable, tests may be repeated on ten meters and the type adjudged in accordance with clause (a).

LABORATORY AND SERVICE TESTS

A. Definitions

56. For purposes of this subdivision, the classification of demand meters as given in Section IX-15 to 17, inclusive, is supplemented by making the following subclasses:

- I. Curve-drawing instruments.
- II. Integrated-demand meters.
  - A. Fixed time interval.
    - 1. Printing.
    - 2. Chart recording.
    - 3. Indicating.
  - B. Fixed blocks of energy.
- III. Lagged-demand meters.
  - A. Proportional timing.
  - B. Exponential timing.

57. Demand meters measure a quantity which is composed of an electrical factor and a time factor. Each demand meter must contain an electrical element, a timing element, and a recording element which may be structurally either separate or combined with each other.

58. **Electrical Element.** The electrical element of a demand meter is that portion, the action or effect of which in response to the electrical quantity to be measured gives a measurement of that electrical quantity. For example, the electrical element of certain demand meters is similar to an ordinary ammeter or wattmeter of the deflection type, and in others it is a watthour meter or other integrating meter, and in still others it is a resistance unit which introduces a heating effect, which is interpreted in terms of amperes or watts.

59. **Timing Element.** The timing element of a demand meter is that mechanism or that feature of the device through which the demand interval (see Section IX, clause 4, page 92) is introduced into the result. While the principal function of the timing element of a demand meter is to measure the demand interval, its subsidiary function in the case of certain types of demand meters is to provide a record of the time of day at which any demand has occurred. The timing element consists either of a clock or its equivalent (for example, an electric motor) or of a lagging device which delays the indications of the electrical ele-

ment. If the timing element is designed to give the time of day in addition to the demand interval, this requirement calls for an accuracy of operation much beyond that required for the demand interval alone.

60. **Recording Element.** The recording element of a demand meter is that mechanism or that feature of the device which records the measurement of the electrical quantity as related to the time interval of the device. In many classes of demand meters this is distinct from the electrical and timing elements, but in certain other classes the electrical, timing and recording elements are interdependent through the principles employed, or through the design.

61. Laboratory and service tests should be conducted, in general, according to the methods approved for watthour meters and with standards complying with the requirements of Section II, clauses 1-13 inclusive, pages 11-14. Service tests of demand meters are further classified the same as service tests of watthour meters, as given in Section VIII, clauses 2 to 11 inclusive, pages 85-86.

B. Laboratory Tests

62. The preparation of meters for these tests should be carried out as outlined for watthour meters in Section VIII, clause 12.

CLASS I. CURVE-DRAWING INSTRUMENTS

63. **Electrical Element.** The electrical element of Class I instruments may be checked against accurate indicating instruments. The electrical element should be adjusted if necessary to indicate within ±2 per cent of full scale indication throughout its working range.

64. **Timing Element.** The timing element of Class I instruments may be checked by comparing the time as indicated by the chart with a standard clock. If the rate of the timing element is inaccurate by more than ±0.25 per cent, it should be corrected.

65. **Recording Element.** The recording element of Class I instruments should be tested for operation, particular attention being given to such matters as the operation of the pen, stylus and reroll attachment.

CLASS II. INTEGRATED-DEMAND METERS

66. **Electrical Element.** The electrical element of Class II demand meters should be tested in accordance with the instructions for watthour meters as given in Section VIII, clause 13 and 14, page 86. Where an electrical contact or mechanical attachment is applied to the meter, it must be in operation during the tests.

67. **Timing Element.** The timing element of Class II demand meters should be tested for accuracy of the demand interval together with the rate of the clock or its equivalent. The demand interval should be checked at least through a complete cycle, that is, one revolution of the timing arbor, and adjusted if the interval is inaccurate by more than ±2 per cent. Where the timing element also serves to keep a record of the time of day at which the demand occurs, it should be adjusted if its rate is inaccurate by more than ±0.25 per cent.

68. **Recording Element.** (a) The recording element of Class II demand meters should be tested for reliability of operation. Where the recording element is operated through electrical contacts on the electrical element or on the timing element or both, the recording element should be tested by connecting it to the other elements and operating them at normal speeds. The reliability of the operation of the recording element may be checked in the laboratory by comparing the number of operations recorded with the correct number. In the case of Class II-A-1 and Class II-B demand meters, the reliability of the recording elements may be determined by: (1) running the electrical element on a constant load and comparing the number of contacts recorded during successive demand intervals; or by (2) connecting a curve-drawing instrument in the same circuit with the electrical element on a constant load and comparing the number of contacts recorded during successive time intervals with the indication of the curve-drawing instrument during the same time; or by (3) comparing the registration of the electrical element with that of the recording element over a given period. Test (3) may be employed only if a long enough time is allowed to elapse to give a sufficiently high registration, but it is not necessary that the load be constant.

(b) In the case of the recording elements of Class II-A-2 and II-A-3 demand meters, the reliability of operation of the recording element can be checked by comparing their indications with those of standard recording elements of the same type connected to the same circuit operated through a relay.

(c) Where the recording element is integral with the watthour meter, that is, actuated by it directly and not through electrical contacts, the tests should be made at or near the rating of the watthour meter. A check should also be made to determine the proper zero setting.

CLASS III. LAGGED-DEMAND METERS

69. (a) In the case of Class III-A demand meters, the electrical element is the indicating element which indicates the demand. The timing element is the integrating electrical device (e.g., a watthour meter) so connected to the indicating element as to

permit it to rise to its maximum indication at a rate proportional to the load; therefore, the watthour meter performs the functions of a timing element. The recording element is the pointer carried forward by the indicating element and left at the maximum position.

(b) The electrical element of Class III-A demand meters may be checked against accurate indicating instruments. Inaccuracies at any part of the scale should not exceed two per cent (2%) of full-scale indication. When this is exceeded, adjustments should be made.

70. **Timing Element.** The timing element of Class II-A demand meters can be checked at rated load by noting the time interval between putting on a constant load and the arrival of the pointer of the recording element at its final position. There should be no load on the demand meter at the start of this test.

71. **Recording Element.** (a) The recording element should be inspected for excessive friction, which would affect the accuracy of the indication, and for constancy of indication under conditions of vibration.

(b) Meters of the thermal type, Class III-B, should be tested by noting the zero indication and subsequently by applying rated full-load current for a sufficient time for a final indication to be reached. Meters inaccurate more than ± 4 per cent should be readjusted. It is not necessary to check the time interval of this class as it is fixed by the design.

72. **Demand Meters Returned from Service.** Demand meters returned from service should be put in first-class operating condition. They should then be given the same tests as are required for new instruments.

C. Installation of Demand Meters

73. **Installation of Demand Meters.** The rules for installation given in Section VI are in general applicable to and should be followed in the case of demand meters.

74. **Location of Demand Meters.** While in general the location of demand meters will be the same as that of corresponding watthour meters, yet it should be noted that clock mechanisms are subject to influence by large temperature changes to a greater degree than are watthour meters. Low temperatures may cause a thickening of the lubricating oil, hence stoppage of the clock, and are particularly to be guarded against. Certain types of recording devices also may be affected by low temperatures or by

excessive moisture. In locations where the air is full of dust, as in cement and flour mills, an auxiliary cover with felt joints may be of considerable value.

D. Service Tests

75. The rules of procedure in testing on the customer's premises given in Section VIII, clauses 16-24, pages 87-88 inclusive, summarize the general principles for testing watthour meters, and these principles are, in general, also applicable to demand meters.

Service testing rules particularly applicable to demand meters of the various classes are given herewith.

CLASS I. CURVE-DRAWING INSTRUMENTS

76. **Electrical Element.** The electrical element of Class I instruments should be checked on a steady load at approximately two-thirds of the instrument rating. Instruments should be adjusted if necessary to indicate within ± 2 per cent of full-scale indication.

77. **Timing Element.** The timing element of Class I instruments may be checked by comparing the time as indicated by the chart with the correct time. Adjustment should be made if the rate of the clock since the last test or inspection has been fast or slow by more than 0.25 per cent. The chart should be reset if appreciably inaccurate.

78. **Recording Element.** The recording element of Class I instruments should be tested for operation, particular attention being given to such matters as the operation of the pen, stylus and reroll attachment.

CLASS II. INTEGRATED-DEMAND METERS

79. Service tests of Class II demand meters may consist of the following:

(a) A test of the electrical element with contacts or driving mechanism of the demand meter in operation.

(b) A check of the accuracy of the timing element.

(c) A check of the demand interval determined by the timing element.

(d) A verification of the constant or registration value of the demand meter, including transformer ratios.

(e) A direct check of the registered demand against the standards or the watthour meter reading when such check is practicable.

80. **Electrical Element.** The electrical element of Class II demand meters should be tested and adjusted in accordance with the rules for watthour meters in Section VIII, clauses 16-31, pages 87-91.

81. **Timing Element.** The timing element may be tested with a stopwatch or suitable timing device to determine the number of revolutions or clock beats in 60 seconds. Where the timing element serves only to determine the demand interval, it should be adjusted if its rate is inaccurate by more than ± 2 per cent. Where the timing element also serves to keep a record of the time of day at which the demand occurs, it should be adjusted if its rate is inaccurate by more than ± 0.25 per cent. This test should not be made when the resetting device (if one is employed) is operating.

The interval test should be made over the full interval of the demand for which the demand meter is adjusted and the inaccuracy should not exceed ± 2 per cent.

82. **Verification of Constant.** The check of the constant may be made by computation or by a count of the revolutions of the disc of the electrical element per increment of the demand registration. The inaccuracy of any increment should not exceed ±2 per cent at full load.

83. **Check of Demand Registration.** On a direct check of the demand registration against standard instruments, an average of three tests, each on a full demand interval, should not show an inaccuracy exceeding ± 4 per cent from two-thirds to full load.

CLASS III. LAGGED-DEMAND METERS

84. Service tests of Class III-A demand meters should be made on a steady load of approximately two-thirds full-scale value maintained for the time interval of the meter or until it has reached final deflection. Adjustment should be made if the inaccuracy exceeds ± 2 per cent of full-scale indication.

85. Service tests of Class III-B instruments should be made on a steady load maintained until final registration is reached. These tests should be made at from two-thirds to full rating of the meter. If the inaccuracy of registration exceeds 4 per cent of full-scale indication, the meter should be corrected.

E. Installation Tests

86. The installation test of a demand meter should be made, as a rule, as soon as practicable after installation. Where an installation inspection is made (see Section IX, clause 93, page 110) the period between the installation of the meter and the installa-

tion test may be longer than otherwise. Where the installation inspection is sufficiently detailed and there has been a preceding laboratory test, the installation test may be omitted altogether.

87. The scope of installation tests should be as follows:

Class I instruments should have the accuracy of the electrical element tested as indicated in Section IX, clause 76, page 107.

Class II demand meters should be given a service test as outlined in Section IX, clauses 79 to 83, pages 107-108, unless some of the checks have previously been obtained in an installation inspection or laboratory test.

Class III-A demand meters should be tested as outlined in Section IX, clauses 84 and 85, page 108.

Class III-B demand meters should be given a careful inspection to see that they are mechanically perfect and that they reset to proper zero point.

F. Periodic Tests

88. Checking a demand meter with accurate standards insures that it is accurate at the beginning of the period between tests. For the meter to remain as nearly correct as possible, all the influences likely to change it must be reduced to a minimum. Some of these influences, such as the effect of wear or collection of dust, produce little change at first, but if allowed to go unremedied will later seriously affect the reliability of operation. The length of time between periodic tests is chosen mainly with a view to testing the meter before this rapid deterioration sets in, but at each test the accuracy should, as far as possible, be corrected by restoring the parts to their original condition rather than by changing the adjustments of the meter.

89. Periodic tests should be made with sufficient frequency so that, in connection with the periodic inspections made at shorter intervals, they will insure continued reliability and commercial accuracy of the type of demand meter as a whole. It cannot be expected that they will be made with sufficient frequency to avoid all accidental interruptions of the operation of the meters, but most of these will be detected by an inspection of the readings.

The proper interval for periodic tests will depend, to a large extent, on the frequency and thoroughness of the periodic inspections as well as upon the inherent reliability of the particular type of meter. In general, testing intervals should be as follows:

(a) The electrical and timing elements of Class I instruments should be tested at intervals of one year.

(b) Class II demand meters should be tested on the same schedule which would be followed for watthour meters of the same rating as their electrical elements. In general, the timing element should be tested at the same time and at the same intervals as the

electrical element with the further limitation that a clock-driven timing element should be thoroughly cleaned and oiled at least once in two years and that motor-timing elements should be tested for accuracy at intervals not to exceed four years.

(c) Class III-A demand meters should have the demand element tested at intervals not to exceed four years.

(d) Class III-B demand meters should be tested or inspected as to electrical connections and zero settings at intervals not to exceed five years. On account of the time required, it is not generally practicable to test these meters in service except when special tests are necessary.

90. **Request Tests.** Request tests are to be treated in accordance with Section VIII, clause 27, page 90, except as modified by the following: The load to be used in making request tests should be chosen with a view to obtaining the best measure of the accuracy with which the meter registers or records the demand of the customer's installation.

91. **Other Service Tests.** The other general classes of service tests as outlined for watthour meters, namely, office tests, repair tests, check tests and referee tests, should be made for the same purposes as in the case of watthour meters, and in general in accordance with the rules laid down in Section VIII, clauses 28-32, pages 90-91.

G. Inspections

92. Inspections of demand meters are divided into two classes: (a) service inspections, (b) statistical inspections. Service inspections are classified as installation inspections, periodic inspections and office inspections.

93. **Installation Inspections.** Installation inspections are made directly after the installation of the meter and should cover the wiring, the ratio of transformation and rating of instrument transformers, meter constant, gear ratios which affect the result, and the general electrical and mechanical parts, to determine that the meter is in good operating condition, properly connected, and so located that good metering results may be expected.

94. **Periodic Inspections.** Periodic inspections are of the same character as installation inspections and may be more or less detailed in accordance with local requirements. They are usually combined with the necessary routine of operating demand meters, such as changing charts or tapes, rewinding clocks and reading the maximum demand. The period of these inspections may be determined by these routine operations, as, for example, the winding of the clock. Demand meters of more complicated construction are

more liable to derangement and require more frequent inspections than the simpler forms. Detailed instructions for making inspections should be given and the records made by the inspector should give a positive indication as to each item which the inspection is designed to cover.

95. **Office Inspection.** Office inspections are made at the request of the office for special purposes.

96. **Statistical Inspections.** Statistical inspections consist of an examination of the results obtained from those demand meters which give a permanent record of the demand. These are useful for determining the accuracy of operation of the meter. They should include:

(a) A verification of the accuracy of the timing element by comparing the indicated time of the final readings with the actual time as reported.

(b) A verification of the reliability of the recording element by noting whether the total number of prints or indications of the demand meter is the number called for by the total elapsed time and also by comparing the total registration as obtained from the indications of the demand meter with that indicated by the watthour meter.

(c) Statistical inspections may in some cases be made with advantage of all readings of certain demand meters, while in many cases it is sufficient if such inspections are made at intervals of six months. Local conditions will often be a determining factor, but statistical inspections should in general constitute a regularly established feature of the maintenance of demand meters.

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